SECOND EDITION

CONSTRUCTION DATABOOK



CONSTRUCTION MATERIALS AND EQUIPMENT








SIDNEY M. LEVY

Construction Databook

About the Author

Sidney M. Levy is an independent construction industry consultant with more than 40 years of experience in the profession. He is the author of numerous books on construction methods and operations, including *Design-Build Project Delivery, Construction Superintendent's Operations Manual,* and *Project Management in Construction* for which he was awarded the British Chartered Institute of Building Silver Medal in the category of Managing Construction.

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Second Edition



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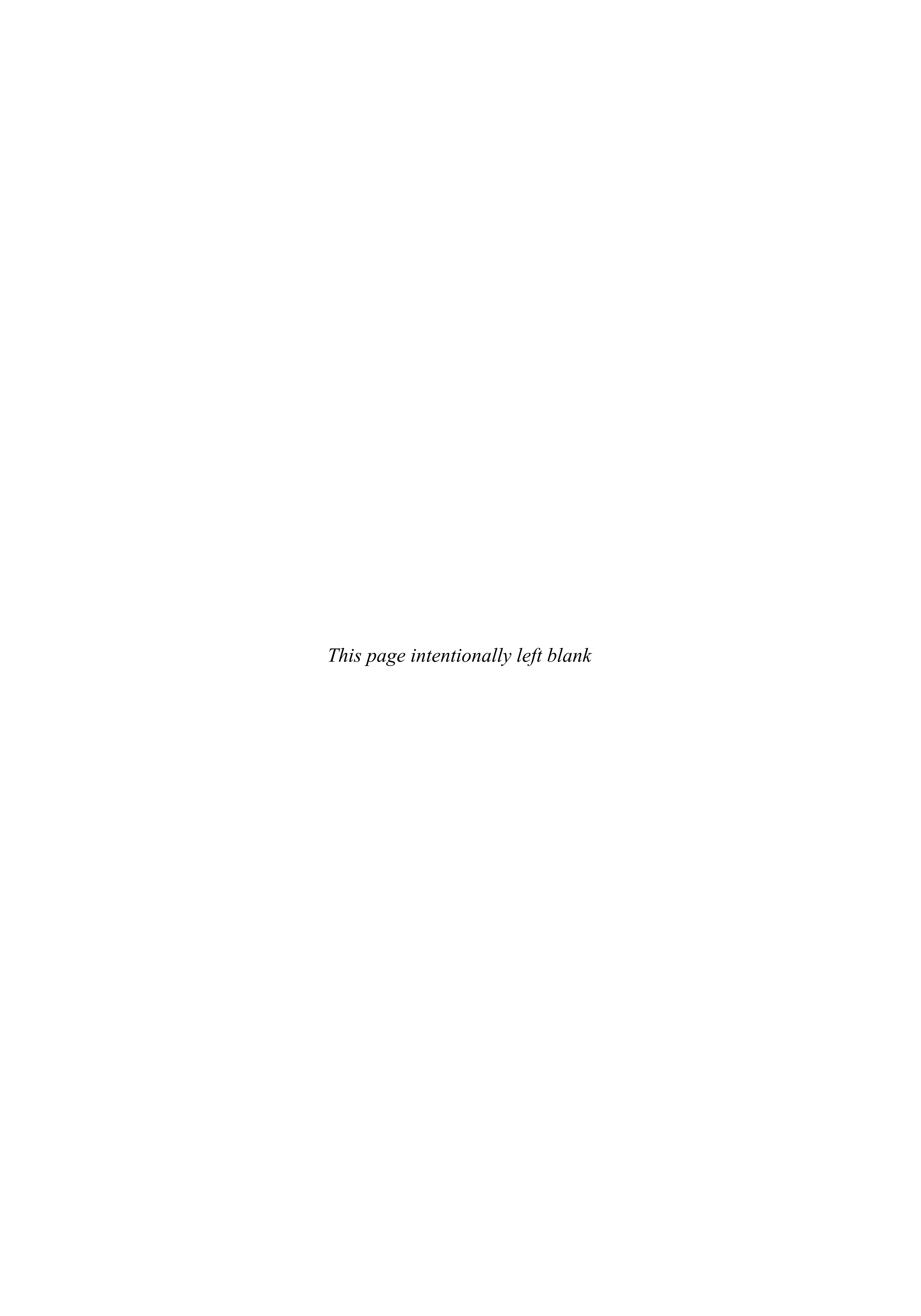
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Introduction

The *Construction DataBook*, *Second Edition*, provides the project manager, construction superintendent, design consultants, facility managers and owners with a one-source guide for the most commonly encountered construction materials and equipment.

Composed of eleven sections ranging, in topics, from excavation and sitework to mechanical and electrical components, the book also includes a handy set of useful tables and formulas. Quick and easy access to informative data on these materials and systems is afforded.

Much of this material has been gleaned from manufacturers and suppliers data but a great deal of these specifications and installation procedures are generic in nature.

The *Construction DataBook, Second Edition* includes several HVAC, plumbing and electrical and alternative energy schematics that explain complex systems in easy-to-understand terms. Installation instructions for subjects as diverse as piles to plastic pipe joining techniques are included in the book. This one-source volume can prove invaluable for office- and field-based design and construction personnel since it contains many of the materials and equipment incorporated in today's building projects.

How many times during project meetings, field visits, or conversations with architects, engineers, general contractors, and subcontractors has it been helpful to have ready access to a concise source of information about product data under discussion? The *Construction DataBook, Second Edition* fulfills that need.

I have selected the construction components, material specifications, and typical installation procedures, that, in my forty years experience in the construction industry appear to be those for which reference material is so often required, and, as usual, required "yesterday."

I hope you find the *Construction DataBook, Second Edition* a worthwhile addition to your construction library.

Sidney M. Levy

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Section

1

Soils, Site Utilities, Sitework Equipment

Contents

1.0.0 Soil Types and Classification

The general classification of soils is divided into the following broad categories:

- Gravel
- Sand
- Silt
- Clay
- Organic

1.0.1 A Glossary to Better Understand Soil Terminology

AASHTO American Association of State Highway and Transportation Officials.

AASHTO T-180 American Association of State Highway and Transportation Officials standard for the modified Proctor test.

AASHTO T-99 American Association of State Highway and Transportation Officials standard for the standard Proctor test.

Aeolian deposits Wind-deposited materials such as sand dunes or other silty-type materials.

Aggregate (coarse or fine) Crushed rock, sand, or gravel that has been graded and may be used as backfill material.

Air gap reading The nuclear density meter test procedure that allows for cancellation of error in reading due to the chemical composition of the soil tested.

Alluvium Material that has been deposited by streams that may no longer exist or that form existing floodplains.

Amplitude The distance an oscillating body moves in one direction from its neutral axis to the outer limit of travel.

Aquifer A geologic formation that provides water in sufficient quantities to create a spring or well.

ASTM American Society for Testing and Materials.

ASTM D 1557 American Society for Testing and Materials standard for the modified Proctor test.

ASTM D 698 American Society for Testing and Materials standard for the standard Proctor test.

Backfill Materials used to refill a cut or other excavation, or the act of such refilling.

Backscatter A method of nuclear density meter soil testing in which the radiation source is placed in contact with the soil surface and density readings are taken from the reflected radiation, the principle being that dense materials absorb more radiation than materials that are not as dense.

Bank A mass of soil that rises above the normal earth level. Generally any soil that is to be dug from its natural position.

Bank-run gravel (run of bank gravel) Gravel as it is excavated from a bank in its natural state.

Bank-yards The measurement of soil or rock taken before digging or disturbing from its original position.

Base The course or layer of materials in a road section on which the actual pavement is placed. This layer may be composed of many different types of materials, ranging from selected soils to crushed stone or gravel.

Base course A layer of material selected to provide a subgrade for some load-bearing structure (such as paving) or to provide some for drainage under a structure above.

Berm An artificial ridge of earth. This term is generally applied to the slide-slopes of a road bed.

Binder A material that passes through a No. 40 U.S. standard sieve that is used to fill voids or hold gravel together.

Borrow pit An excavation from which fill material is taken.

Boulder A rock fragment with a diameter larger than 12 in. (304.8 mm).

Capillary action The cohesive, adhesive, or tensive force that causes water that is contained within soil channels to rise or depress on the normal horizontal plane or level.

Cemented soil Soil in which particles are held together by a chemical agent, such as calcium carbonate.

Centrifugal force The pulling force of an eccentric weight when put in rotary motion that may be changed by varying the rotational speed and/or mass of the eccentric and/or center of gravity (shape) of the eccentric weight.

Clay A cohesive mineral soil consisting of particles less than 0.002 mm in equivalent diameter, a soil textural class, or a fine-grained soil with more than 50 percent passing through a No. 200 sieve that has a high plasticity index in relation to its liquid limit.

Clean Free of foreign material. When used in reference to sand or gravel, it means the lack of a binder.

Cobble A rock fragment, generally oblong or rounded, with an average dimension ranging from 3 in. (75 mm) to 12 in. (305 mm).

Cohesion Shear resistance of soil at zero normal stress; also the quality of some soil particles to attract and stick to like particles; sticking together.

Cohesionless soil A soil that when air-dried in an unconfined space has little cohesion when submerged.

Cohesive material A soil having properties of cohesion.

Cohesive soil A soil that when in an unconfined state has considerable strength when air-dried and submerged.

Compacted yards The cubic measurement of backfill after it has been placed and compacted in fill.

Compaction A process to decrease voids between soil particles when subjected to the forces applied by special equipment.

Compressibility The property of a soil to remain in a compressed state after compaction.

Contact reading A reading by a nuclear density meter when the bottom of the meter is in full contact with the compacted material to be tested.

Core A cylindrical sample of an underground formation, cut and raised by a rotary hollow bit drill.

Crown The center elevation of a road surface used to encourage drainage.

Datum Any level surface used as a plane of reference to measure elevations.

Density The mass of solid particles in a sample of soil or rock.

Double amplitude The distance an oscillating body moves from its neutral axis to the outer limit of its travel in opposite directions.

Dry soil Soil that does not exhibit visible signs of moisture content.

Dynamic linear force The force pounds per inch (lb/in.) seen by the soil as produced by a vibratory roller. Calculated by dividing the centrifugal force by the width of the compacting surface(s).

Eccentric A mass of weight off-balanced to produce centrifugal force (lb) and being part of the exciter unit that produces vibration.

Elasticity Properties that cause soil to rebound after compaction.

Embankment A fill whose top is higher than the adjoining natural compaction.

*End result specification*s Compaction specifications that allow results instead of method specifications to be the determining factor in the selection of equipment.

Exciter The component of a vibratory compactor that creates centrifugal force by means of a power-driven eccentric weight.

Fines The smallest soil particles (less than 0.002 mm) in a graded soil mixture.

Fissured soil Soil material that has a tendency to break along definite planes of fracture with little resistance.

Foot or shoe The bottom part of a vibratory impact rammer contacting the soil.

Frequency The rate at which a vibrating compactor operates, usually expressed in vibrations per minute (VPM).

Glacial till Unstratified glacial materials deposited by the movement of ice and composed of sand, clay, gravel, and boulders in any proportion.

Grade Usually defined as the surface elevation of the ground at points where it meets a structure; also, surface slope.

Grain distribution curve A soil analysis graph showing the percentage of particle size variations by weight.

Granular material A type of soil whose particles are coarser than cohesive material and do not stick to each other.

Granular soil Gravel, sand, or silt with little or no clay content. It has no cohesive strength, cannot be molded when moist, and crumbles easily when dry.

Gravel Round or semiround particles of rock that pass through a 3-in. (76.2-mm) sieve and are retained by a No. 4 U.S. standard sieve [approximately $^1/_4$ in. (6.35 mm)]. It is also defined as an aggregate, consisting of particles that range in size from $^1/_4$ in. (6.35 mm) to 3 in. (76.2 mm).

Gumbo Clays that are distinguished in the plastic state by a soapy or waxy appearance and great toughness.

Hardpan Soil that has become rocklike because of the accumulation of cementing minerals, such as calcium carbonate, in the soil.

Impervious Resistant to movement of water.

In situ The natural, undisturbed soil in place.

Internal friction The soil particle's resistance to movement within the soil mass. For sand, the internal friction is dependent on the gradation, density, and shape of the grain and is relatively independent of the moisture content. For a clay, internal friction varies with the moisture content.

Layered system Two or more distinctly different soil or rock types arranged in layers.

Lift A layer of fill as spread or compacted. A measurement of material depth. The amplitude of a rammer's shoe. The rated effective soil depth a compactor can achieve.

Liquid limit The water content at which the soil changes from a plastic to a liquid state.

Loam A soft, easily worked soil that contains sand, silt, clay, and decayed vegetation.

Loess A uniform aeolian deposit of silty material having an open structure and relatively high cohesion because of the cementation of clay or marl.

Marl Calcareous clay that contains from 35 to 65 percent calcium carbonate.

Muck Mud rich in humus or decayed vegetation.

Mud Generally, any soil containing enough water to make it soft and plastic.

Optimum moisture content Water content at which a soil can be compacted to a maximum-unit dry-unit weight.

Organic clay/soil/silt Clay/soil/silt with high organic content.

Pass A working trip or passage of an excavating, grading, or compaction machine.

Peat A soft, light swamp soil consisting mostly of decayed vegetation.

Perched water table A water table of generally limited area that appears above the normal free-water elevation.

Plasticity A property of soil that allows the soil to be deformed or molded without cracking or causing an appreciable volume change.

Plasticity index The numeric difference between a soil's liquid limit and its plastic limit.

Plastic limit The lowest water content of a soil, at which the soil just begins to crumble when rolled into a cylinder approximately $\frac{1}{8}$ in. (3.17 mm) in diameter.

Proctor modified A moisture–density test of more rigid specifications than the standard Proctor test. The basic difference is use of a heavier weight dropped from a greater distance in laboratory determinations.

Proctor standard A test method developed by R. R. Proctor for determining the density–moisture relationship in soils. It is almost universally used to determine the maximum density of any soil so that specifications may be properly prepared for field construction requirements.

Quicksand Fine sand or silt that is prevented from stabilizing by a continuous upward movement of underground water.

Relative compaction The dry unit of weight of soil compared to the maximum unit weight obtained in a laboratory compaction test and expressed as a ratio.

Silt A soil composed of particles between 0.00024 in. (0.006 mm) and 0.003 in. (0.076 mm) in diameter.

Soil The loose surface material of the earth's crust.

Specific gravity The ratio of weight in air of a given volume of solids at a stated temperature to the weight in air of an equal volume of distilled water at the stated temperature.

Stabilize To make soil firm and prevent it from moving.

Static linear force The force in pounds per inch (lb/in.) seen by the soil as produced by a nonvibratory roller. Calculated by dividing the dead weight of the compactor by the width of the compacting surface(s).

Subbase The layer of selected material placed to furnish strength to the base of a road. In areas where construction goes through marshy, swampy, unstable land, it is often necessary to excavate the natural material in the roadway and replace it with more stable materials. The material used to replace the unstable natural soils is generally called subbase material, and when compacted is known as the subbase.

Subgrade The surface produced grading native earth, or inexpensive materials that serve as a base for a more expensive paving.

VPM Vibrations per minute, derived by the rate of revolutions the exciter makes each minute.

1.1.0 ASTM Unified Soil Classification (USC) System

The American Society for Testing and Materials refers to the Unified Soil Classification system in its ASTM D-2487 specification, the Unified Soil Classification (USC) system.

Unified Soil Classification (USC) System (from ASTM D 2487)

Major Divisions			Group Symbol	Typical Names
Coarse-Grained Soils More than 50% retained on the 0.075 mm (No. 200) sieve	**Gravels** 50% or more of coarse fraction retained on the 4.75 mm (No. 4) sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands 50% or more of coarse fraction passes the 4.75 (No. 4) sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		Sands with Fines	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
Fine-Grained Soils More than 50% passes the 0.075 mm (No. 200) sieve	**Silts and Clays** Liquid Limit 50% or less		ML	Inorganic silts, very fine sands, rock four, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly/sandy/silty/lean clays
			OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays Liquid Limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays or high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck, and other highly organic soils

Prefix: G = Gravel, S = Sand, M = Silt, C = Clay, O = Organic
Suffix: W = Well Graded, P = Poorly Graded, M = Silty, L = Clay, LL < 50%, H = Clay, LL > 50%

1.1.1 ASTM Terminology

ASTM terminology, as presented in the USC divisions, refers to material retained after passing through a sieve.

The basic reference for the Unified Soil Classification System is ASTM D 2487. Terms include:

Coarse-Grained Soils More than 50 percent retained on a 0.075 mm (No. 200) sieve.

Fine-Grained Soils 50 percent or more passes a 0.075 mm (No. 200) sieve.

Gravel Material passing a 75-mm (3-inch) sieve and retained on a 4.75-mm (No. 4) sieve.

Coarse Gravel Material passing a 75-mm (3-inch) sieve and retained on a 19.0-mm (3/4-inch) sieve.

Fine Gravel Material passing a 19.0-mm (3/4-inch) sieve and retained on a 4.75-mm (No. 4) sieve.

Sand Material passing a 4.75-mm sieve (No. 4) and retained on a 0.075-mm (No. 200) sieve.

Coarse Sand Material passing a 4.75-mm sieve (No. 4) and retained on a 2.00-mm (No. 10) sieve.

Medium Sand Material passing a 2.00-mm sieve (No. 10) and retained on a 0.475-mm (No. 40) sieve.

Fine Sand Material passing a 0.475-mm (No. 40) sieve and retained on a 0.075-mm (No. 200) sieve.

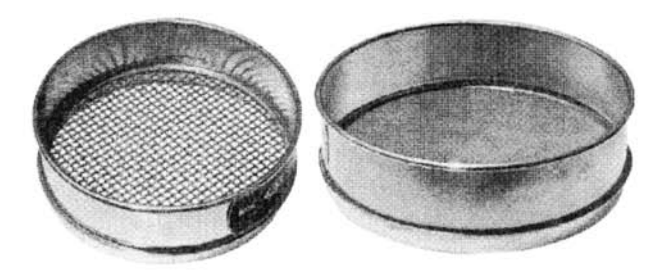
Clay Material passing a 0.075-mm (No. 200) sieve that exhibits plasticity, and strength when dry (PI ^{3} 4).

Silt Material passing a 0.075-mm (No. 200) sieve that is non-plastic, and has little strength when dry (PI < 4).

Peat Soil of vegetable matter.

1.1.2 Sieve Size Reference and Sieve Size Chart

Sieve size reference and sieve size chart with both U.S. and metric sieve openings. The terminology is based upon various soils being able to pass through a sieve size containing openings of various sizes.



U.S.A. Sieve Series and Equivalents—A.S.T.M. E-11-87

Sieve Designation		Sieve Opening		Nominal Wire Diameter	
Standard (a)	Alternative	mm	in (approx. equivlnts.)	mm	in (approx. equivlnts.)
125 mm	5"	125	5.00"	8.00	.3150"
106 mm	4.24"	106	4.24"	6.40	.2520"
100 mm	4"(b)	100	4.00"	6.30	.2480"
90 mm	3.5"	90	3.50"	6.08	.2394"
75 mm	3"	75	3.00"	5.80	.2283"
63 mm	2.5"	63	2.50"	5.50	.2165"
53 mm	2.12"	53	2.12"	5.15	.2028"
50 mm	2"(b)	50	2.00"	5.05	.1988"
45 mm	1.75"	45	1.75"	4.85	.1909"
37.5 mm	1.5"	37.5	1.50"	4.59	.1807"
31.5 mm	1.25"	31.5	1.25"	4.23	.1665"
26.5 mm	1.06"	26.5	1.06"	3.90	.1535"
25.0 mm	1"(b)	25.0	1.00"	3.80	.1496"
22.4 mm	7/8"	22.4	0.875"	3.50	.1378"
19.0 mm	3/4"	19.0	0.750"	3.30	.1299"
16.0 mm	5/8"	16.0	0.625"	3.00	.1181"
13.2 mm	.530"	13.2	0.530"	2.75	.1083"
12.5 mm	1/2"(b)	12.5	0.500"	2.67	.1051"
11.2 mm	7/16"	11.2	0.438"	2.45	.0965"
9.5 mm	3/8"	9.5	0.375"	2.27	.0894"
8.0 mm	5/16"	8.0	0.312"	2.07	.0815"
6.7 mm	.265"	6.7	0.265"	1.87	.0736"
6.3 mm	1/4"(b)	6.3	0.250"	1.82	.0717"
5.6 mm	No. 3-1/2(c)	5.6	0.223"	1.68	.0661"
4.75 mm	No. 4	4.75	0.187"	1.54	.0606"
4.00 mm	No. 5	4.00	0.157"	1.37	.0539"
3.35 mm	No. 6	3.35	0.132"	1.23	.0484"
2.80 mm	No. 7	2.80	0.11"	1.10	.0430"
2.36 mm	No. 8	2.36	0.0937"	1.00	.0394"
2.00 mm	No. 10	2.00	0.0787"	.900	.0345"
1.70 mm	No. 12	1.70	0.0661"	.810	.0319"
1.40 mm	No. 14	1.40	0.0555"	.725	.0285"
1.18 mm	No. 16	1.18	0.0469"	.650	.0256"
1.00 mm	No. 18	1.00	0.0394"	.580	.0228"
850 µm	No. 20	0.850	0.0331"	.510	.0201"
710 µm	No. 25	0.710	0.0278"	.450	.0177"
660 µm	No. 30	0.600	0.0234"	.390	.0154"
500 µm	No. 35	0.500	0.0197"	.340	.0134"
425 µm	No. 40	0.425	0.0165"	.290	.0114"
355 µm	No. 45	0.355	0.0139"	.247	.0097"
300 µm	No. 50	0.300	0.0117"	.215	.0085"
250 µm	No. 60	0.250	0.0098"	.180	.0071"
212 µm	No. 70	0.212	0.0083"	.152	.0060"
180 µm	No. 80	0.180	0.0070"	.131	.0052"
150 µm	No. 100	0.150	0.0059"	.110	.0043"
125 µm	No. 120	0.125	0.0049"	.091	.0036"
106 µm	No. 140	0.106	0.0041"	.076	.0030"
90 µm	No. 170	0.090	0.0035"	.064	.0025"
75 µm	No. 200	0.075	0.0029"	.053	.0021"
63 µm	No. 230	0.063	0.0025"	.044	.0017"
53 µm	No. 270	0.053	0.0021"	.037	.0015"
45 µm	No. 325	0.045	0.0017"	.030	.0012"
38 µm	No. 400	0.038	0.0015"	.025	.0010"
32 µm	No. 450		0.00126"	.0011	
25 µm	No. 500		0.00098"	.001	
20 µm	No. 635		0.00079"	.0008	

(a) These standard designations correspond to the values for test sieve apertures recommended by the International Standards Organization Geneva, Switzerland.
(b) These sieves are not in the fourth root of 2 Series, but they have been included because they are in common usage.
(c) These numbers (3-1/2 to 400) are the approximate number of openings per linear inch but it is preferred that the sieve be identified by the standard designation in millimeters or microns (1000 microns = 1 mm.)

1.1.3 American Association of State Highway and Transportation Officials (AASHTO) Soil Classification System

American Association of State Highway and Transportation Officials (AASHTO) has a somewhat different soil classification system to be used by the states in developing specifications for highway construction purposes.

AASHTO Soil Classification System

The **AASHTO Soil Classification System** was developed by the American Association of State Highway and Transportation Officials, and is used as a guide for the classification of soils and soil-aggregate mixtures for highway construction purposes. The classification system was first developed by in 1929,[1] but has been revised several times since.

AASHTO Soil Classification System (from AASHTO M 145 or ASTM D3282)

General Classification	**Granular Materials (35% or less passing the 0.075 mm sieve)**							**Silt-Clay Materials (>35% passing the 0.075 mm sieve)**			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, % passing											
2.00 mm (No. 10)	50 max	...	...	...	...	...	...	...	...	...	...
0.425 (No. 40)	30 max	50 max	51 min	...	...	...	...	...	...	...	...
0.075 (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid Limit	...		...	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min[1]
Usual types of significant constituent materials	stone fragments, gravel and sand		fine sand	silty or clayey gravel and sand				silty soils		clayey soils	
General rating as a subgrade	excellent to good							fair to poor			

Note (1): Plasticity index of A-7-5 subgroup is equal to or less than the LL - 30. Plasticity index of A-7-6 subgroup is greater than LL - 30

From Wikipedia, the free encyclopedia.

[1] Hogentogler, C.A., Terzaghi, K. (May 1929). " Interrelationship of load, road and subgrade", *Public Roads*; pp. 37–64.

1.1.4 Properties of Soils, U.S. Department of Agriculture (USDA)

Properties of soils modified by the U.S. Department of Agriculture (USDA) to reflect soil groups that range from excellent to unsatisfactory based upon drainage, frost heave susceptibility, and potential volume changes.

Soil Group	Unified Soil Classification Symbol	Soil Description	Drainage Characteristics[1]	Frost Heave Susceptibility[2]	Volume Change Potential Expansion[3]
Group I *Excellent*	GW	Well-graded gravel, gravel-sand mixtures, little or no fines	Good	Low (F1)	Low
	GP	Poorly graded gravels or gravel-sand mixtures, little or no fines	Good	Low (F1) to Medium (F2)	Low
	SW	Well-graded sands, gravely sands, little or no fines	Good	Medium (F2)	Low
	SP	Poorly graded sands, gravely sands, little or no fines	Good	Medium (F2)	Low
	GM	Silty gravels, gravel-sand-clay mixtures	Medium	Low (F1) to High (F3)	Low
	SM	Silty sand, sand-silt mixtures	Medium	Mekium (F2) to High (F3)	Low
Group II *Fair to Good*	GC	Clayey gravels, gravel-sand-clay mixtures	Medium	High (F3)	Low
	SC	Clayey sand, sand-clay mixtures	Medium	High (F3)	Low
	ML	Inorganic silts and very fine sands, rock flour, silty fine sands or clayey silts with slight plasticity	Medium	Very High (F4)	Low
	CL	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	Medium	High (F3) to Very High (F4)	Medium
Group III *Poor*	CH	Inorganic clays of high plasticity, fat clays	Poor	High (F3)	High to Very High
	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils	Poor	Very High (F4)	High
Group IV *Unsatisfactory*	OL	Organic silts and organic silty clays of low plasticity	Poor	High (F3)	Medium
	OH	Organic sands of medium to high plasticity, organic silts	Unsatisfactory	High (F3)	High
	PT	Peat and other high organic soils	Unsatisfactory	High (F3)	High

Source: Table modified from the U.S. Department of Agriculture (www.usda.gov).
1 Percolation rate for good drainage is over 4 inches per hour, medium drainage is 2 to 4 inches per hour, and poor drainage is less than 2 inches per hour.
2 After Coduto, D.P.(2001). *Foundation Design.* Prentice-Hall. F1 indicates soils that are least susceptible to frost heave, and F4 indicates soils that are most susceptible to frost heave.
3 For expansive soils, contact a geotechnical engineer for verification of design assumptions. Dangerous expansion might occur if soils classified as having medium to very high potential expansion types are dry but then are subjected to future wetting.

1.1.5 USDA and *FEMA Coastal Construction Manual* Bearing Capacity Data

USDA and *FEMA Coastal Construction Manual* data include bearing capacity data, shear strength and angle of internal friction data, and grading of various types of soils as excellent, fair to good, or poor.

Table 7 Engineering Properties of Soils

Soil Group	Unified Soil Classification Symbol	Bearing Capacity (psf)	Undrained Shear Strength[1] (psf)	Angle of Internal Friction (degrees)
Group I *Excellent*	GW	2,700-3,000	NA	38-46
	GP	2,700-3,000	NA	38-46
	SW	800-1,200 (loose)	NA	30-46 (loose to dense)
	SP	800-1,200 (loose)	NA	30-36 (loose to dense)
	GM	2,700-3,000	NA	38-46
	SM	1,600-3,500 (firm)	NA	28-40 (firm)
Group II *Fair to Good*	GC	2,700-3,000	NA	38-46
	SC	1,600-3,500 (firm)	NA	30-34 (dense)
	ML	2,000	NA	30-34 (dense)
	CL	600-1,200 (soft) — 3,000-4,500 (stiff)	0-250 (soft) — 1,000-1,200 (stiff)	NA
Group III *Poor*	CH	600-1,200 (soft) — 3,000-4,500 (stiff)	250-500 (soft) — 2,000-4,000 (stiff)	NA
	MH	2,000	1,600	NA

Source: Table modified from the U.S. Department of Agriculture (www.usda.gov), *FEMA Coastal Construction Manual* (www.fema.gov), and Bardet, J. (1997). *Experimental Soil Mechanics*. Prentice-Hall.

[1] The undrained shear strength is also commonly referred to as cohesion in saturated clays.

psf = pounds per square foot NA = not applicable

1.1.6 Typical Soil Bearing Capacity Categories

Typical soil bearing capacities can be roughly categorized as follows:

- Crystalline bedrock — 12,000 pounds per square foot
- Sedimentary rock — 6,000 pounds per square foot
- Sandy gravel or gravel — 5,000 pounds per square foot
- Sand, silty sand, clayey sand, silty gravel — 3,000 pounds per square foot
- Clay, sandy clay, silty clay — 2,000 pounds per square foot

Source: Table 401.4.1, *CABO-1 & 2 Family Houses Code*, 1995.

1.2.0 Soil Test Boring Report

The geotechnical report assembled by an owner when a new construction project is anticipated will include test borings to acquaint bidding contractors with the general nature of the site's subsurface conditions.

LOG OF BORING No. B-1

CLIENT: | **DATE:** 6-22-99 | #02995604 | **RIG:** CME 75

SITE: | **PROJECT:**

GRAPHIC LOG	DESCRIPTION	DEPTH ft.	USCS SYMBOL	NUMBER	TYPE	RECOVERY in.	SPT – N BLOWS/ft	WATER CONTENT %	DRY UNIT WT. pcf	UNCONFINED STRENGTH q_u psf	ATTERBERG LIMITS LL, PL, PI
	6" GRAVEL LEAN CLAY, silty trace organics, gray brown, trace dark brown and red brown, medium (Possible Fill)				PA						
			CL	1	SS	14	7	34.1		2000*	45,21,34
	LEAN CLAY, calcareous, trace sand and limestone gravel dark brown, brown, very stiff (Possible Fill)	5			HS						
		10	CL	2	SS	6	5	18.6		7000*	45,23,22
					HS						
	LEAN CLAY, trace silt, gray brown, trace dark gray, red brown and dark brown, stiff to very stiff	15	CL	3	SS	24	9	24.1		5500*	
					HS						
		20	CL	4	SS	24	10	22.3		3500*	44,20,24
					HS						
	LEAN CLAY, silty, gray brown, trace dark brown, stiff to very stiff	25	CL	5	SS	24	5	27.6		2500*	
					HS						
		30	CL	6	SS	24	19	26.5		5000*	42,18,24
					HS						
	Trace limonites at 34.0' LEAN TO FAT CLAY, gray brown, trace dark brown, very stiff	35	CL-CH	7	SS	24	14	23.5		5000*	
					HS						

1.2.1 Stratum Description Column in Boring Log

A stratum description column is included in the boring log and makes reference to soils description in more general terms, such as topsoil, gravel, and dense or medium sand. This log and report is often accompanied by the civil engineer's soils classification terminology that mostly parallels that of the USC and includes a component gradation designation and a fines fraction chart.

1.2.1.1 Fines Fraction, Plasticity

Fines fraction, plasticity, component gradation terms, and density/consistency tables accompany the civil engineer's soils report. The smallest thread diameter rolled portion of the table refers to the smallest diameter the soil sample can be rolled into by hand.

COMPONENT GRADATION TERMS

MATERIAL	FRACTION	SIEVE SIZE
GRAVEL	COARSE	3/4" TO 3"
	FINE	NO. 4 TO 3/4"
SAND	COARSE	N0. 10 TO NO. 4
	MEDIUM	NO. 40 TO NO. 10
	FINE	NO. 200 TO NO. 40
FINES		PASSING NO. 200

FINES FRACTION

PLASTICITY	PI	NAME	SMALLEST THREAD DIA ROLLED
NON-PLASTIC	0	SILT	NONE
SLIGHT	1-5	Clayey SILT	1/4"
LOW	5-10	SILT & CLAY	1/8"
MEDIUM	10-20	CLAY & SILT	1/16"
HIGH	20-40	Silty CLAY	1/32"
VERY HIGH	>40	CLAY	1/64"

1.2.1.2 Bedrock Weathering Classifications

BEDROCK WEATHERING CLASSIFICATION

GRADE	SYMBOL	DIAGNOSTIC FEATURES
Fresh	F	No visible signs of decomposition or discoloration. Rings under hammer impact.
Slightly Weathered	WS	Slight discoloration inwards from open fractures, otherwise similar to F.
Moderately Weathered	WM	Discoloration throughout. Weaker minerals such as feldspar decomposed. Strength somewhat less than fresh rock but cores cannot be broken by hand or scraped by knife. Texture preserved.
Highly Weathered	WH	Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becoming indistinct but fabric preserved.
Completely Weathered	WC	Minerals decomposed to soil but fabric and structure preserved (Saprolite). Specimens easily crumbled or penetrated.
Residual Soil	RS	Advanced state of decomposition resulting in plastic soils. Rock fabric and structure completely destroyed. Large volume change.

1.2.1.3 Mechanical Properties of Rock

TABLE 1. MECHANICAL PROPERTIES OF VARIOUS ROCKS

Rock	Young's Modulus at Zero Load (10^5 kg/cm^2)	Bulk Density (g/cm^3)	Porosity (percent)	Compressive Strength (kg/cm^2)	Tensile Strength (kg/cm^2)
Granite	2 - 6	2.6-2.7	0.5-1.5	1,000-2,500	70-250
Microgranite	3 - 8				
Syenite	6 - 8				
Diorite	7-10			1,800-3,000	150-300
Dolerite	8-11	3.0-3.05	0.1-0.5	2,000-3,500	150-350
Gabbro	7-11	3.0-3.1	0.1-0.2	1,000-3,000	150-300
Basalt	6-10	2.8-2.9	0.1-1.0	1,500-3,000	100-300
Sandstone	0.5-8	2.0-2.6	5 - 25	200-1,700	40-250
Shale	1-3.5	2.0-2.4	10 - 30	100-1,000	20-100
Mudstone	2 - 5				
Limestone	1 - 8	2.2-2.6	5 - 20	300-3,500	50-250
Dolomite	4-8.4	2.5-2.6	1 - 5	800-2,500	150-250
Coal	1 - 2			50-500	20-50
Quartzite		2.65	0.1-0.5	1,500-3,000	100-300
Gneiss		2.9-3.0	0.5-1.5	500-2,000	50-200
Marble		2.6-2.7	0.5-2	1,000-2,500	70-200
Slate		2.6-2.7	0.1-0.5	1,000-2,000	70-200

Note:
1. For the igneous rocks listed above Poisson's ratio is approximately 0.25.
2. For a certain rock type, the strength normally increases with increase in density and increase in Young's modulus. (After Farmer, 1968)
3. Taken from *"Foundation Engineering Handbook"* by Winterkorn and Fong, Van Nostrand Reinhold, pg. 72.

By permission: Atlas Systems, Inc., Independence, Missouri.

1.3.0 Soil Compaction Methods

Soil compaction is simply the method by which the density of soil can be increased by mechanical or often natural ways. Ponding of water on shallow layers of soil can cause soil consolidation, as can placing an overburden on soils that were previously excavated and placed in an area where compacted soil is required. Both of these methods are time-consuming and not very practical on the typical fast-moving construction project.

Compacting soils accomplishes a number of things:

- It provides structural integrity to the soil, thereby increasing its load-bearing capacity.
- It prevents later settlement of nonstructural soils.
- It reduces water seepage and the resultant heave and contraction.

Soils can be compacted by various types of mechanical action:

- Vibration. A downward force is created by rotating a concentric weight or piston attached to a roller.
- Static. Weight is merely applied by the force of a heavy piece of equipment rolling back and forth across the area to be compacted.
- Impact. This is a repeated ramming action.

1.3.1 Soil Compaction Equipment

Compaction machines produce two types of forces: *frequency* and *amplitude*. Frequency is the speed at which an eccentric shaft within the compaction machine rotates and is expressed as vibrations per minute (VPM). Amplitude is the maximum movement of the vibrating body from one axis to another. A machine with double amplitude exhibits that movement in both directions from its axis.

1.3.1.1 Flat Plate Compactor



1.3.1.2 Rammer-Type Compactor



1.3.1.3 Walk-behind Trench Compactor



1.3.1.4 Riding Tandem Drum Compactor



1.3.2 Importance of Depth of Soil Layer to Be Compacted

Civil engineers are quick to point out that areas to be backfilled must be compacted in 6-in. layers. By understanding the way in which compaction equipment works, it is rather easy to see why this 6-in. rule is important.

As the compaction machine rides over the soil to be compacted, the impact travels to the hard surface below the newly placed layer and then returns upward. This action places all the soil particles in action, and compaction commences. With a short distance to travel, say 6 in., the impact down and back is quicker, and therefore proper compaction occurs more quickly. The thicker the uncompacted soil layer, the longer it will take to compact.

Overcompaction can also occur if the compaction equipment is operated over the area for too long a period. This will produce cracks and fissures in compacted soil, resulting in reduced overall density.

1.3.3 Quick Reference of Compaction Equipment Applications for Various Types of Soils

For granular soils compaction by vibration is the most effective. Vibration decreases friction between soil particles, thereby allowing them to eliminate all air voids and rearrange themselves into a very tightly compacted configuration. This vibratory effect penetrates deep in the soil so that slightly thicker layers can be compacted, requiring fewer passes. In smaller areas vibratory plate compactors are used; in large areas, vibratory rollers provide better production.

The smaller the soil particle, the higher the natural resonant frequencies must be; the larger the particle, the lower the required frequency. A lightweight vibratory late compactor with a high frequency of 6250 vibrations per minute and a low amplitude is the best equipment for finer and medium sands.

For cohesive soils, impact equipment is preferable. The impact force creates a shearing effect on the soil that binds the flat, pancake-shaped soil particles together and in the process squeezes out air pockets. A high ramming speed of 500 to 700 impacts per minute also creates a vibratory effect that works well with granular as well as cohesive soils. A vibratory trench roller with sheep's foot-like cleats also performs well on cohesive soils because it creates the shearing action necessary for proper compaction.

Summation

- Granular soils—vibratory plate or smooth drum vibratory roller.
- Cohesive soils—rammer or vibratory trench roller.
- Mixed soils—use any rammer or trench roller.

1.3.4 Pea Gravel Compaction

Some contractors are of the opinion that pea gravel does not require compaction, but that concept is incorrect. Because the surface of pea gravel is irregular and not nearly round, as it appears to the eye, it too should be compacted so that each particle settles and essentially compacts.

1.3.5 Compaction Methods

There are several methods by which the compaction of soil can be determined.

1.3.6.0 Hand Test

Squeezing a soil sample in one's hand is one easy, quick way to get an unscientific but pretty good idea whether the soil's moisture content and composition will be readily compactable. When squeezed in the hand, the soil sample that is moldable and breaks into a few small pieces probably will compact properly. If the soil sample is powdery and falls apart easily in the hand, it is an indication that moisture will be required to gain acceptable compaction. And if the sample has too much moisture content, it will stick to one's palm and fingers and retain its shape when dropped.

1.3.6.1 Standard Proctor Test, ASTM D 698

The more definitive and scientific approach to ensuring the proper compaction of soils is the Proctor test, which determines the maximum achievable density of the soil sample by driving out the moisture and then weighing the sample.

Objective — To determine the optimum moisture content and dry density of a compacted soil sample.

Procedure

1. Obtain 2500 g of oven dry (air dry will work, but not as well) soil passed through the #4 sieve.

2. Weigh 1 "bread pan" moisture content container and record the weight on the data sheet.

3. Weigh a 4 inch diameter compaction mold. (V = 1/30 of a cubic foot)

4. Add enough water to your sample to obtain a 14% moisture content (remember water content is Ww/Ws). If using air dry soil, remember to consider the moisture content of air dry soil and only add enough water to get to 14% moisture. If your air dry soil already has 4% moisture, you need to take that into account.

5. Compact the soil into the mold in **three layers** using a **5.5** pound hammer and 25 blows per layer. Make sure that on the last layer, your compacted sample is just above (1/4" or so) the top of the mold so it can be trimmed and weighed.

6. Weigh the mold and the sample (in pounds) and record on your data sheet.

7. Take a representative sample of the soil (about half of it evenly distributed from the entire sample) and place in a "bread pan" moisture content container. Weigh the sample, record the data, and place in the oven. Work quickly because water is being lost as time progresses.

8. Repeat steps 1 through 7 twice, increasing the moisture content to 18% for the 2nd point and then 22% for the third point.

9. Obtain all weights the following day and plot moisture content vs. dry unit weight to scale on graph paper and indicate optimum moisture and maximum dry unit weight.

1.3.6.3 Modified Proctor Test, ASTM D 1557

Basically this is the same as the standard Proctor test except a 10-lb (4.5-kg) hammer is dropped 18 in. (45.7 cm) on five layers of soil.

Objective — To determine the optimum moisture content and dry density of a compacted soil sample.

Procedure (The same as the Standard except you use a 10 lb hammer, 18" drop, 5 layers)

1. Obtain 2500 g of oven dry (air dry will work, but not as well) soil passed through the #4 sieve.

2. Weigh 3 "bread pan" moisture content containers individually and record weights on the data sheet in your manual.

3. Weigh a 4 inch diameter compaction mold. (V = 1/30 of a cubic foot)

4. Add enough water to your sample to obtain a 12% moisture content (300 g of water).

5. Compact the soil into the mold in **FIVE** layers using a **10 pound hammer** and 25 blows per layer. Make sure that on the last layer, your compacted sample is just above (1/4" or so) the top of the mold so it can be trimmed and weighed.

6. Weigh the mold and the sample (in pounds) and record on your data sheet.

7. Take a representative sample of the soil (about half of it evenly distributed from the entire sample) and place in a "bread pan" moisture content container. Weigh the sample, record the data, and place in the oven. Work quickly because water is being lost as time progresses.

8. Repeat steps 1 through 7 twice, increasing the moisture content to 15% for the 2nd point and then 18% for the third point.

9. Obtain all weights the following day and plot moisture content vs. dry unit weight to scale on graph paper and indicate optimum moisture and maximum dry unit weight.

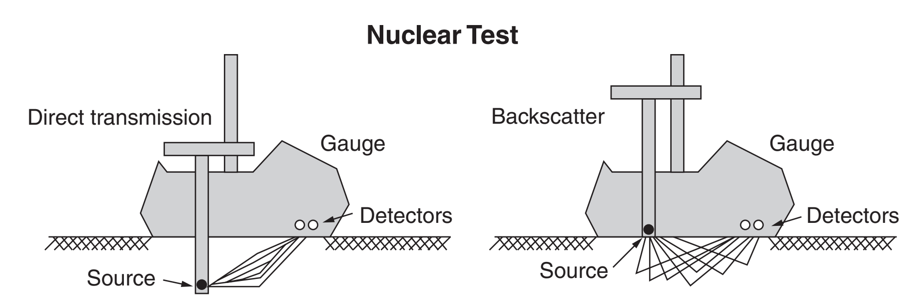
1.3.6.3 Nuclear Density Test, ASTM D 2292-91

This method of testing uses a radioactive isotope, cesium 137, in a probe driven into the soil. The isotope gives off gamma rays which radiate back to the detectors located in the bottom of the device. Since dense soil absorbs more radiation than loosely packed soil, the readings provide the soil density. There are two basic types of probes: in one, a radioactive source is mounted near the tip of the probe, and in the other, the probe is inserted into a preformed hole.

1.3.6.4 Diagram of a Nuclear Density Testing Device

Nuclear Density (ASTM D 2292-91)
Nuclear density meters are a quick and fairly accurate way of determining density and moisture content. The meter uses a radioactive isotope source (cesium 137) at the soil surface (backscatter) or from a probe placed into the soil (direct transmission). The isotope source gives off photons (usually gamma rays) which radiate back to the matter's detectors on the bottom of the unit. Dense soil absorbs more radiation than loose soil and the readings reflect overall density. Water content (ASTM D 3017) can also be read, all within a few minutes. A relative Proctor density with the compaction results from the test.

Nuclear Test



1.4.0 Excavation Equipment—Excavators

From mini-excavators to large tracked giants, there are several manufacturers producing equipment to suit every need. Moline, Illinois-based John Deere presents such a complete line; a portion of each type is illustrated here.

1.4.1 Mini-excavators

John Deere model 17D.

Operating Weights

	3 ft. 1 in. (0.93 m) Standard Arm and Standard Counterweight	3 ft. 8 in. (1.13 m) Long Arm and Extra Counterweight
With Full Fuel Tank and 175-lb. (79 kg) Operator		
With Rubber Track	4,173 lb. (1893 kg)	4,364 lb. (1979 kg)
With Steel Track	4,319 lb. (1959 kg)	4,508 lb. (2045 kg)

Operating Dimensions

	3 ft. 1 in. (0.93 m) Standard Arm and Standard Counterweight	3 ft. 8 in. (1.13 m) Long Arm and Extra Counterweight
A Maximum Digging Height	11 ft. 8 in. (3.56 m)	12 ft. (3.66 m)
B Maximum Dumping Height	8 ft. 4 in. (2.53 m)	8 ft. 8 in. (2.63 m)
C Maximum Digging Depth	7 ft. 1 in. (2.17 m)	7 ft. 9 in. (2.37 m)
D Maximum Digging Reach	12 ft. 10 in. (3.90 m)	13 ft. 5 in. (4.08 m)
E Minimum Front Swing Radius	5 ft. 1 in. (1.54 m)	5 ft. 4 in. (1.63 m)
F Transport Length	11 ft. 9 in. (3.59 m)	11 ft. 11 in. (3.64 m)
Bucket Breakout Force	3,597 lb. (16.0 kN)	3,597 lb. (16.0 kN)
Arm Breakout Force	2,316 lb. (10.3 kN)	2,046 lb. (9.1 kN)

Machine Dimensions

Blade Width				
Minimum	3 ft. 3 in. (0.98 m)			
Maximum	4 ft. 2 in. (1.28 m)			
Blade Height	10.2 in. (260 mm)			
	3 ft. 1 in. (0.93 m) Standard Arm, Standard Counterweight, and Rubber Track	3 ft. 8 in. (1.13 m) Long Arm, Extra Counter-weight, and Rubber Track	3 ft. 1 in. (0.93 m) Standard Arm, Standard Counterweight, and Steel Track	3 ft. 8 in. (1.13 m) Long Arm, Extra Counter-weight, and Steel Track
G Upperstructure Width	3 ft. 3 in. (0.98 m)	3 ft. 3 in. (0.98 m)	3 ft. 3 in. (0.98 m)	3 ft. 3 in. (0.98 m)
H Overall Height to Roof	7 ft. 10 in. (2.40 m)	7 ft. 10 in. (2.40 m)	7 ft. 10 in. (2.40 m)	7 ft. 10 in. (2.40 m)
I Track Width	9 in. (230 mm)	9 in. (230 mm)	9 in. (230 mm)	9 in. (230 mm)
J Undercarriage Width				
Minimum	3 ft. 2 in. (0.97 m)	3 ft. 2 in. (0.97 m)	3 ft. 2 in. (0.97 m)	3 ft. 2 in. (0.97 m)
Maximum	4 ft. 2 in. (1.28 m)	4 ft. 2 in. (1.28 m)	4 ft. 2 in. (1.28 m)	4 ft. 2 in. (1.28 m)
K Ground Clearance	6.5 in. (165 mm)	6.5 in. (165 mm)	5.7 in. (145 mm)	5.7 in. (145 mm)
L Tail Swing Radius	27 in. (675 mm)	30 in. (755 mm)	27 in. (675 mm)	30 in. (755 mm)
M Engine Cover Height	4 ft. (1.23 m)	4 ft. (1.23 m)	4 ft. (1.23 m)	4 ft. (1.23 m)
N Maximum Blade Lift Above Ground	11.2 in. (285 mm)	11.2 in. (285 mm)	11.2 in. (285 mm)	11.2 in. (285 mm)
O Maximum Blade Drop Below Ground	9.4 in. (240 mm)	9.4 in. (240 mm)	9.4 in. (240 mm)	9.4 in. (240 mm)
P Sprocket Center To Idler Center	4 ft. (1.21 m)	4 ft. (1.21 m)	3 ft. 11 in. (1.20 m)	3 ft. 11 in. (1.20 m)
Q Track Length	5 ft. 2 in. (1.57 m)	5 ft. 2 in. (1.57 m)	5 ft. 1 in. (1.55 m)	5 ft. 1 in. (1.55 m)
R Counterweight Clearance	17 in. (435 mm)	17 in. (435 mm)	16 in. (415 mm)	16 in. (415 mm)

Lift Capacities

	3 ft. 1 in. (0.93 m) Standard Arm, Standard Counterweight, and Rubber Track	3 ft. 8 in. (1.13 m) Long Arm, Extra Counter-weight, and Rubber Track	3 ft. 1 in. (0.93 m) Standard Arm, Standard Counterweight, and Steel Track	3 ft. 8 in. (1.13 m) Long Arm, Extra Counter-weight, and Steel Track
Over Front, Blade Down (limited by hydraulics)	979 lb. (444 kg)	963 lb. (437 kg)	979 lb. (444 kg)	963 lb. (437 kg)
Over Side	500 lb. (227 kg)	559 lb. (254 kg)	524 lb. (238 kg)	583 lb. (264 kg)

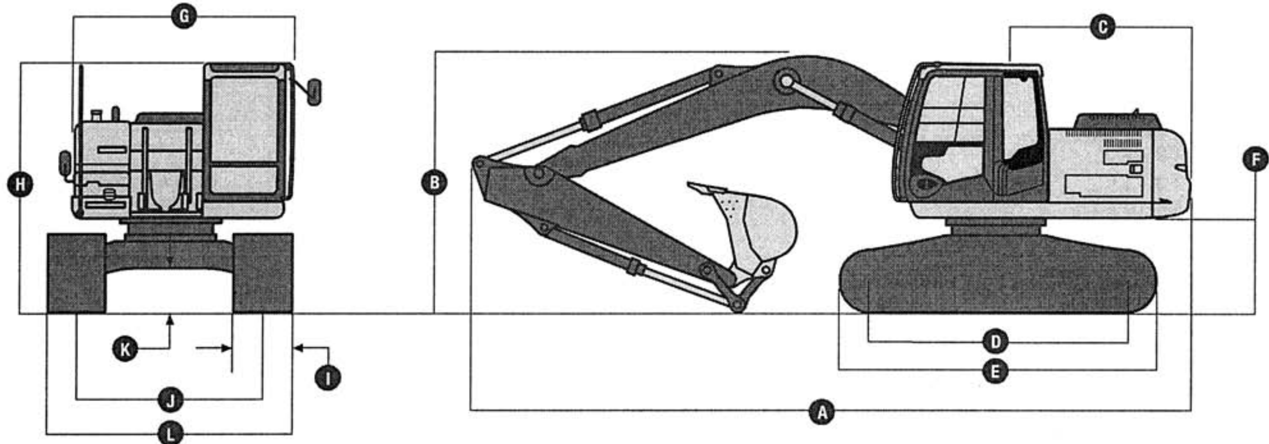
By permission, Deere & Company, Moline, Illinois.

1.4.2 Midsized Track Excavator

John Deere model 160D.

Machine Dimensions

		Arm Length 8 ft. 6 in. (2.60 m)	*Arm Length 10 ft. 2 in. (3.01 m)*
A	Overall Length	28 ft. 1 in. (8.55 m)	28 ft. 2 in. (8.58 m)
B	Overall Height	9 ft. 5 in. (2.87 m)	10 ft. 2 in. (3.11 m)
C	Rear-End Length/Swing Radius	8 ft. 2 in. (2.49 m)	
D	Distance Between Idler/Sprocket Centerline	10 ft. 2 in. (3.10 m)	
E	Undercarriage Length	12 ft. 10 in. (3.92 m)	
F	Counterweight Clearance	3 ft. 3 in. (1001 mm)	
G	Upperstructure Width	8 ft. 2 in. (2.48 m)	
H	Cab Height	9 ft. 8 in. (2.95 m)	
I	Track Width with Triple Semi-Grouser Shoes	24 in. (600 mm) / 28 in. (700 mm)	
J	Gauge Width	6 ft. 6 in. (1.99 m)	
K	Ground Clearance	19 in. (470 mm)	
L	Overall Width with Triple Semi-Grouser Shoes		
	24 in. (600 mm)	8 ft. 6 in. (2.60 m)	
	28 in. (700 mm)	8 ft. 10 in. (2.70 m)	



Lift Charts

Boldface italic type indicates hydraulic-limited capacities; lightface type indicates stability-limited capacities, in lb. (kg). Ratings are at bucket lift hook, using standard counterweight, situated on firm, level, uniform supporting surface. Figures do not exceed 87 percent of hydraulic capacity or 75 percent of weight needed to tip machine.

Load Point	5 ft. (1.52 m)		10 ft. (3.05 m)		15 ft. (4.57 m)		20 ft. (6.10 m)		25 ft. (7.62 m)	
Height	Over Front	Over Side	Over Front	Over Side	Over Front	Over Side	Over Front	Over Side	Over Front	Over Side
With 8-ft. 6-in. (2.60 m) arm, 0.78-cu.-yd. (0.60 m³) bucket, and 24-in. (600 mm) triple semi-grouser shoes										
20 ft. (6.10 m)							***5,470 (2481)***	***5,470 (2481)***		
15 ft. (4.57 m)							***6,568 (2979)***	6,411 (2908)		
10 ft. (3.05 m)					***9,265 (4203)***	***9,265 (4203)***	***7,684 (3485)***	6,107 (2770)	***5,803 (2632)***	4,073 (1847)
5 ft. (1.52 m)					***12,523 (5680)***	8,920 (4046)	***9,160 (4155)***	5,733 (2600)	6,443 (2922)	3,922 (1779)
Ground Line					14,137 (6412)	8,388 (3805)	8,959 (4064)	5,438 (2467)	6,300 (2858)	3,789 (1719)
–5 ft. (–1.52 m)			***13,758 (6241)***	***13,758 (6241)***	13,949 (6327)	8,226 (3731)	8,810 (3996)	5,302 (2405)		
–10 ft. (–3.05 m)	***18,000 (8165)***	***18,000 (8165)***	***16,758 (7601)***	16,167 (7333)	14,052 (6374)	8,315 (3772)	8,875 (4026)	5,361 (2432)		
–15 ft. (–4.57 m)			***15,450 (7008)***	***15,450 (7008)***	***10,825 (4910)***	8,315 (3772)				
With 8-ft. 6-in. (2.60 m) arm, 0.78-cu.-yd. (0.60 m³) bucket, and 28-in. (700 mm) triple semi-grouser shoes										
20 ft. (6.10 m)							***5,470 (2481)***	***5,470 (2481)***		
15 ft. (4.57 m)							***6,568 (2979)***	6,507 (2952)		
10 ft. (3.05 m)					***9,265 (4203)***	***9,265 (4203)***	***7,684 (3485)***	6,202 (2813)	***5,803 (2632)***	4,146 (1881)
5 ft. (1.52 m)					***12,523 (5680)***	9,057 (4108)	***9,160 (4155)***	5,829 (2644)	6,552 (2972)	3,995 (1812)
Ground Line					14,356 (6512)	8,525 (3867)	9,105 (4130)	5,534 (2510)	6,410 (2908)	3,862 (1752)
–5 ft. (–1.52 m)			***13,758 (6241)***	***13,758 (6241)***	14,169 (6427)	8,363 (3793)	8,956 (4062)	5,398 (2448)		
–10 ft. (–3.05 m)	***18,000 (8165)***	***18,000 (8165)***	***16,798 (7619)***	16,411 (7444)	***14,174 (6429)***	8,452 (3834)	9,021 (4092)	5,457 (2475)		
–15 ft. (–4.57 m)			***15,450 (7008)***	***15,450 (7008)***	***10,825 (4910)***	8,832 (4006)				

By permission, Deere & Company, Moline, Illinois.

1.4.2 Midsized Track Excavator (Continued)

Ground Pressure

Triple Semi-Grouser Shoes

24 in. (600 mm)	6.16 psi (42.5 kPa)
28 in. (700 mm)	5.40 psi (37.2 kPa)

Serviceability

Refill Capacities

Fuel Tank	85 gal. (320.0 L)
Cooling System	23 qt. (22.0 L)
Engine Oil with Filter	16 qt. (15.0 L)
Hydraulic Tank	33 gal. (125.0 L)
Hydraulic System	52.0 gal. (196.8 L)
Gearbox	
Propel (each)	5.0 qt. (4.7 L)
Swing	6.0 qt. (5.7 L)

Operating Weights

With Full Fuel Tank; 175-lb. (79 kg) Operator; 36-in. (914 mm), 0.81-cu.-yd. (0.62 m³), 1,373-lb. (623 kg) Heavy-Duty Bucket; 10-ft. 2-in. (3.10 m) Arm; 7,275-lb. (3300 kg) Counterweight; 12-ft. 10-in. (3.92 m) Undercarriage Length; and Triple Semi-Grouser Shoes

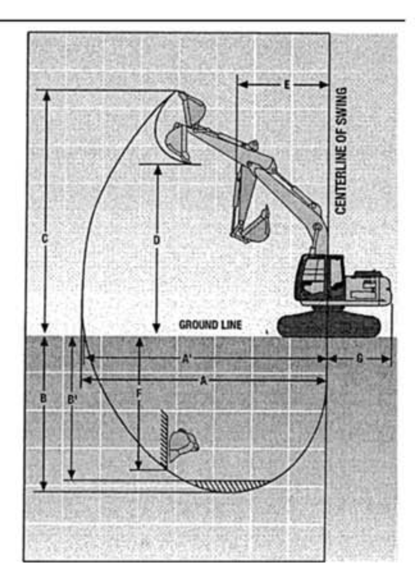
24 in. (600 mm)	39,508 lb. (17 937 kg)
28 in. (700 mm)	39,980 lb. (18 151 kg)

Optional Components

Undercarriage with Triple Semi-Grouser Shoes	
24 in. (600 mm)	13,911 lb. (6316 kg)
28 in. (700 mm)	14,383 lb. (6530 kg)
Upperstructure with Full Fuel Tank (less front attachments and 7,275-lb. [3300 kg] counterweight)	7,917 lb. (3594 kg)
One-Piece Boom (with arm cylinder)	2,864 lb. (1300 kg)
Arm with Bucket Cylinder and Linkage	
8 ft. 6 in. (2.60 m)	1,735 lb. (788 kg)
10 ft. 2 in. (3.10 m)	1,925 lb. (874 kg)
Boom Lift Cylinders (2) Total Weight	675 lb. (306 kg)
36-in. (914 mm), 0.81-cu.-yd. (0.62 m³) Heavy-Duty Bucket	1,373 lb. (623 kg)
Counterweight (standard)	7,275 lb. (3300 kg)

Operating Dimensions

	Arm Length 8 ft. 6 in. (2.60 m)	*Arm Length 10 ft. 2 in. (3.10 m)*
Arm Force with 36-in. (914 mm), 0.81-cu.-yd. (0.62 m³) Heavy-Duty Bucket	19,352 lb. (86.1 kN)	17,243 lb. (76.7 kN)
Bucket Digging Force with 36-in. (914 mm), 0.81-cu.-yd. (0.62 m³) Heavy-Duty Bucket	22,697 lb. (101.0 kN)	22,697 lb. (101.0 kN)
Lifting Capacity Over Front at Ground Level 20-ft. (6.1 m) Reach	9,105 lb. (4134 kg)	9,094 lb. (4129 kg)
A Maximum Reach	29 ft. 1 in. (8.87 m)	30 ft. 7 in. (9.33 m)
A' Maximum Reach at Ground Level	28 ft. 7 in. (8.70 m)	30 ft. 1 in. (9.16 m)
B Maximum Digging Depth	19 ft. 7 in. (5.98 m)	21 ft. 4 in. (6.49 m)
B' Maximum Digging Depth at 8-ft. (2.44 m) Flat Bottom	18 ft. 10 in. (5.74 m)	20 ft. 7 in. (6.27 m)
C Maximum Cutting Height	29 ft. 2 in. (8.88 m)	29 ft. 11 in. (9.13 m)
D Maximum Dumping Height	20 ft. 3 in. (6.17 m)	21 ft. 0 in. (6.40 m)
E Minimum Swing Radius	9 ft. 7 in. (2.91 m)	9 ft. 7 in. (2.92 m)
F Maximum Vertical Wall	16 ft. 11 in. (5.16 m)	18 ft. 8 in. (5.69 m)
G Tail Swing Radius	8 ft. 2 in. (2.49 m)	8 ft. 2 in. (2.49 m)



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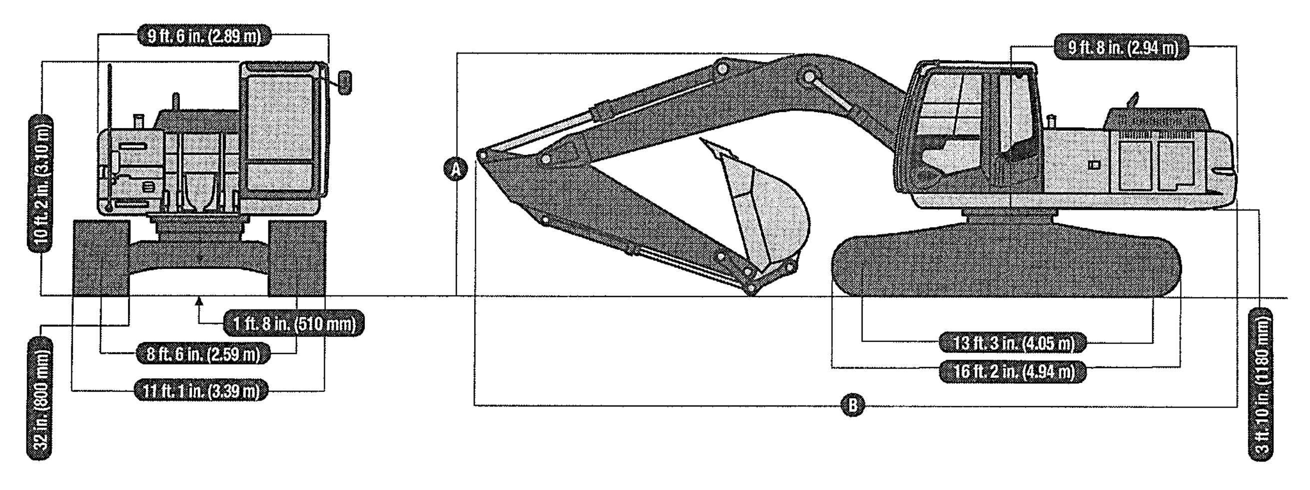
1.4.3 Large Track Excavator

John Deere model 270D.

Dimensions

A 10-ft. 2-in. (3.11 m) arm. . . . . 10 ft. 5 in. (3.17 m)
12-ft. 4-in. (3.75 m) arm. . . . . 11 ft. 0 in. (3.35 m)

B 10-ft. 2-in. (3.11 m) arm. . . . . 33 ft. 11 in. (10.34 m)
12-ft. 4-in. (3.75 m) arm. . . . . 35 ft. 3 in. (10.74 m)



Lift Capacities

Boldface italic type indicates hydraulic-limited capacities; lightface type indicates stability-limited capacities, in lb. (kg). Ratings at bucket lift hook; machine equipped with 1.75-cu.-yd. (1.34 m³), 42-in. (1065 mm), 2,279-lb. (1034 kg) bucket; 13,447-lb. (6100 kg) counterweight; standard gauge; and situated on firm, uniform supporting surface. Total load includes weight of cables, hook, etc. Figures do not exceed 87 percent of hydraulic capacities or 75 percent of weight needed to tip machine. All lift capacities are based on SAE J1097.

Load Point	10 ft. (3.05 m)		15 ft. (4.57 m)		20 ft. (6.10 m)		25 ft. (7.62 m)		30 ft. (9.15 m)	
Height	Over Front	Over Side	Over Front	Over Side	Over Front	Over Side	Over Front	Over Side	Over Front	Over Side
With 12-ft. 4-in. (3.75 m) arm and 32-in. (800 mm) triple semi-grouser shoes										
25 ft. (7.62 m)							***8,490 (3851)***	***8,490 (3851)***		
20 ft. (6.10 m)							***8,629 (3914)***	***8,629 (3914)***	***5,984 (2714)***	***5,984 (2714)***
15 ft. (4.57 m)							***9,676 (4389)***	***9,676 (4389)***	***9,609 (4359)***	7,937 (3600)
10 ft. (3.05 m)			***17,039 (7729)***	***17,039 (7729)***	***13,189 (5982)***	***13,189 (5982)***	***11,405 (5173)***	10,668 (4839)	***10,524 (4774)***	7,680 (3484)
5 ft. (1.52 m)			***24,377 (11 057)***	22,290 (10 111)	***16,795 (7618)***	14,398 (6531)	***13,401 (6079)***	10,091 (4577)	***11,626 (5274)***	7,371 (3343)
Ground Line			***28,866 (13 094)***	20,936 (9497)	***19,727 (8948)***	13,562 (6152)	***15,195 (6892)***	9,601 (4355)	12,245 (5554)	7,096 (3219)
–5 ft. (–1.52 m)	***15,885 (7205)***	***15,885 (7205)***	***30,355 (13 769)***	20,481 (9290)	***21,412 (9712)***	13,102 (5943)	16,083 (7295)	9,284 (4211)	12,055 (5468)	6,922 (3140)
–10 ft. (–3.05 m)	***22,504 (10 208)***	***22,504 (10 208)***	***29,877 (13 552)***	20,489 (9294)	***21,738 (9860)***	12,972 (5884)	15,965 (7242)	9,178 (4163)	***10,392 (4714)***	6,920 (3139)
–15 ft. (–4.57 m)	***30,876 (14 005)***	***30,876 (14 005)***	***27,577 (12 509)***	20,821 (9444)	***20,489 (9294)***	13,131 (5956)	***15,518 (7039)***	9,328 (4231)		
–20 ft. (–6.10 m)	***30,941 (14 035)***	***30,941 (14 035)***	***22,517 (10 214)***	21,537 (9769)	***16,452 (7463)***	13,673 (6202)				
With 10-ft. 2-in. (3.11 m) arm and 32-in. (800 mm) triple semi-grouser shoes										
20 ft. (6.10 m)							***10,107 (4585)***	***10,107 (4585)***		
15 ft. (4.57 m)					***11,760 (5334)***	***11,760 (5334)***	***10,993 (4986)***	10,981 (4981)	***8,349 (3787)***	7,778 (3528)
10 ft. (3.05 m)			***20,484 (9291)***	***20,484 (9291)***	***14,959 (6785)***	***14,959 (6785)***	***12,603 (5717)***	10,494 (4760)	***11,531 (5230)***	7,587 (3441)
5 ft. (1.52 m)			***27,306 (12 386)***	21,575 (9786)	***18,319 (8309)***	14,121 (6405)	***14,426 (6544)***	9,976 (4525)	***12,445 (5645)***	7,332 (3326)
Ground Line			***28,596 (12 971)***	20,733 (9404)	***20,773 (9423)***	13,441 (6097)	***15,959 (7239)***	9,564 (4338)	12,256 (5559)	7,117 (3228)
–5 ft. (–1.52 m)	***14,458 (6558)***	***14,458 (6558)***	***30,272 (13 731)***	20,588 (9339)	***21,875 (9922)***	13,133 (5957)	16,127 (7315)	9,337 (4235)	12,156 (5514)	7,026 (3187)
–10 ft. (–3.05 m)	***23,292 (10 565)***	***23,292 (10 565)***	***29,066 (13 184)***	20,762 (9418)	***21,566 (9782)***	13,130 (5956)	16,121 (7312)	9,332 (4233)		
–15 ft. (–4.57 m)	***29,503 (13 382)***	***29,503 (13 382)***	***25,803 (11 704)***	21,225 (9628)	***19,419 (8808)***	13,422 (6088)				

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1.4.3 Large Track Excavator (Continued)

Ground Pressure Data

Average Ground Pressure
32-in. (800 mm) Triple Semi-Grouser Shoes
(recommended for general/soft terrain) . . . 5.84 psi (40.3 kPa)

Capacities (U.S.)

Fuel Tank. . . . . 132 gal. (500 L)
Cooling System . . . . 31.6 qt. (29.9 L)
Engine Lubrication, Including Filter . . . . 26 qt. (24.6 L)
Hydraulic Tank. . . . . 39 gal. (148 L)
Hydraulic System . . . . 63.4 gal. (240 L)
Propel Gearbox (each) . . . . 9 qt. (8.5 L)
Swing Drive. . . . . 8 qt. (7.6 L)

SAE Operating Weights

With Full Fuel Tank; 175-lb. (79 kg) Operator; 1.75-cu.-yd. (1.34 m³), 42-in. (1065 mm), 2,279-lb. (1034 kg) Bucket; 12-ft. 4-in. (3.75 m) Arm; 13,447-lb. (6100 kg) Counterweight; and 32-in. (800 mm) Triple Semi-Grouser Shoes. . . . . 63,425 lb. (28 770 kg)

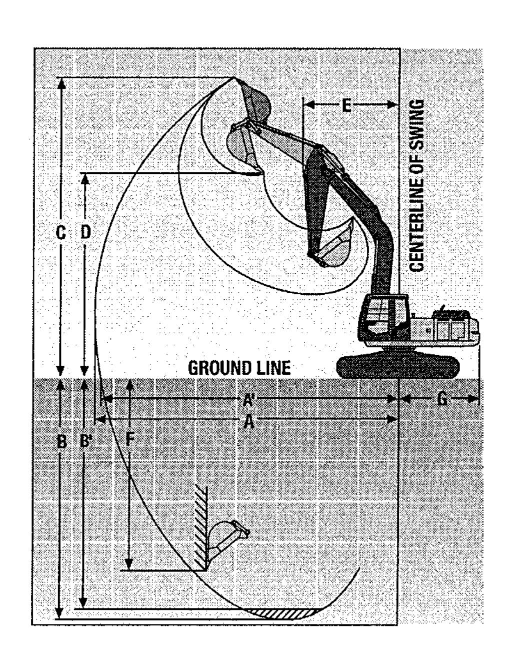
Component Weights

Undercarriage
32-in. (800 mm) Triple Semi-Grouser Shoes . . . 25,937 lb. (11 765 kg)
One-Piece Boom (with arm cylinder) . . . . 5,086 lb. (2307 kg)
Arm with Bucket Cylinder and Linkage
10 ft. 2 in. (3.11 m). . . . . 3,102 lb. (1407 kg)
12 ft. 4 in. (3.75 m). . . . . 3,298 lb. (1496 kg)
Boom Lift Cylinders (2) Total Weight . . . . 1,098 lb. (494 kg)
1.75-cu.-yd. (1.34 m³), 42-in. (1065 mm)
Heavy-Duty High-Capacity Bucket. . . . . 2,279 lb. (1034 kg)
Counterweight. . . . . 13,447 lb. (6100 kg)

Operating Information

	Arm Length 10 ft. 2 in. (3.11 m)	*Arm Length 12 ft. 4 in. (3.75 m)*
Arm Force with 32-in. (800 mm) Triple Semi-Grouser Shoes*	29,518 lb. (131.3 kN)	25,979 lb. (115.55 kN)
Bucket Digging Force with 32-in. (800 mm) Triple Semi-Grouser Shoes*	37,480 lb. (166.7 kN)	37,480 lb. (166.7 kN)
Lifting Capacity Over Front @ Ground Level 20-ft. (6.1 m) Reach*	20,773 lb. (9423 kg)	19,727 lb. (8948 kg)
A Maximum Reach	35 ft. 3 in. (10.74 m)	37 ft. 1 in. (11.30 m)
A' Maximum Reach @ Ground Level	34 ft.7 in. (10.55 m)	36 ft. 6 in. (11.12 m)
B Maximum Digging Depth	23 ft. 10 in. (7.26 m)	25 ft. 11 in. (7.91 m)
B' Maximum Digging Depth @ 8-ft. (2.44 m) Flat Bottom	23 ft. 2 in. (7.05 m)	25 ft. 8 in. (7.72 m)
C Maximum Cutting Height	32 ft. 10 in. (10.01 m)	34 ft. 4 in. (10.46 m)
D Maximum Dumping Height	23 ft. 2 in. (7.07 m)	24 ft. 7 in. (7.49 m)
E Minimum Swing Radius	13 ft. 7 in. (4.41 m)	12 ft. 9 in. (3.89 m)
F Maximum Vertical Wall	20 ft. 1 in. (6.11 m)	23 ft. 1 in. (7.03 m)
G Tail Swing Radius	9 ft. 8 in. (2.94 m)	9 ft. 8 in. (2.94 m)

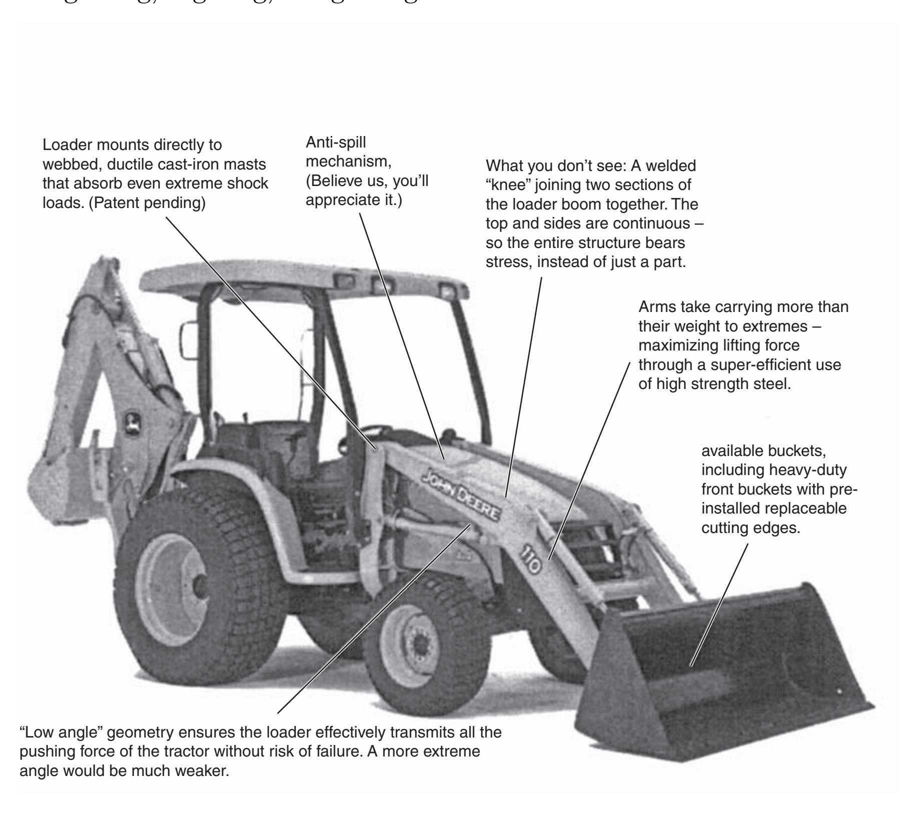
*Digging forces and lift capacities with power boost.

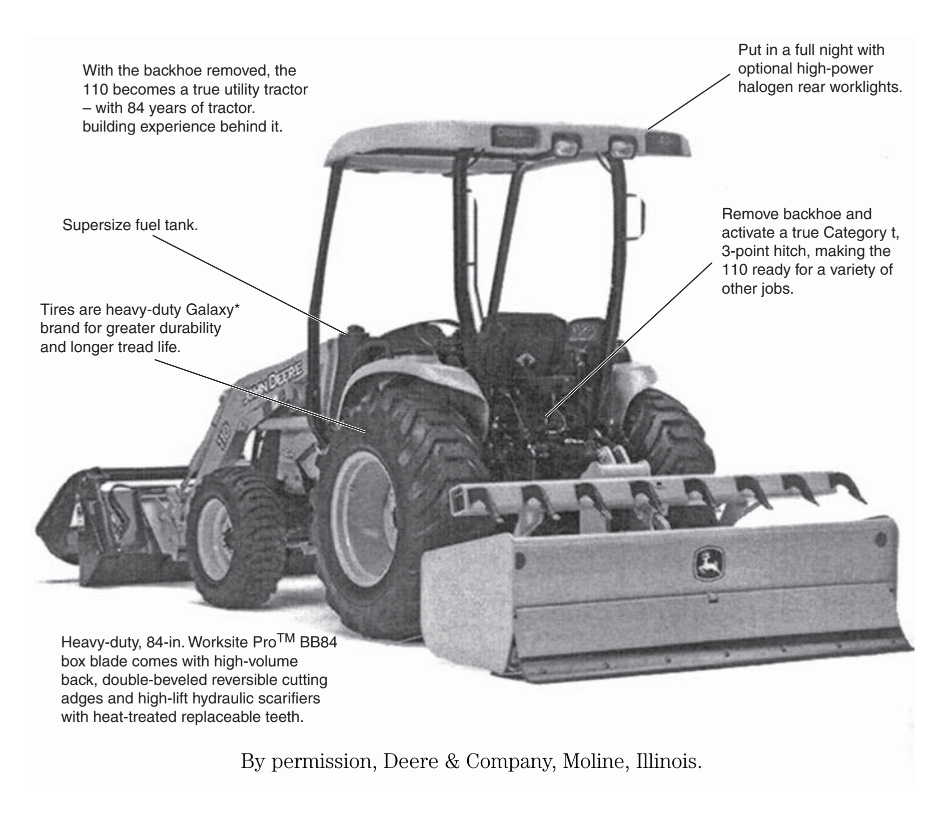


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1.5.0 Small Rubber Tire Backhoe

Small rubber tire backhoes, 100 Series. A 43-hp, small backhoe with a maximum depth reach of 10 ft (3.05 m) and a lift height reach of 9.67 ft (2.94 m). Miscellaneous attachments are available for general grading, auguring, and grading.





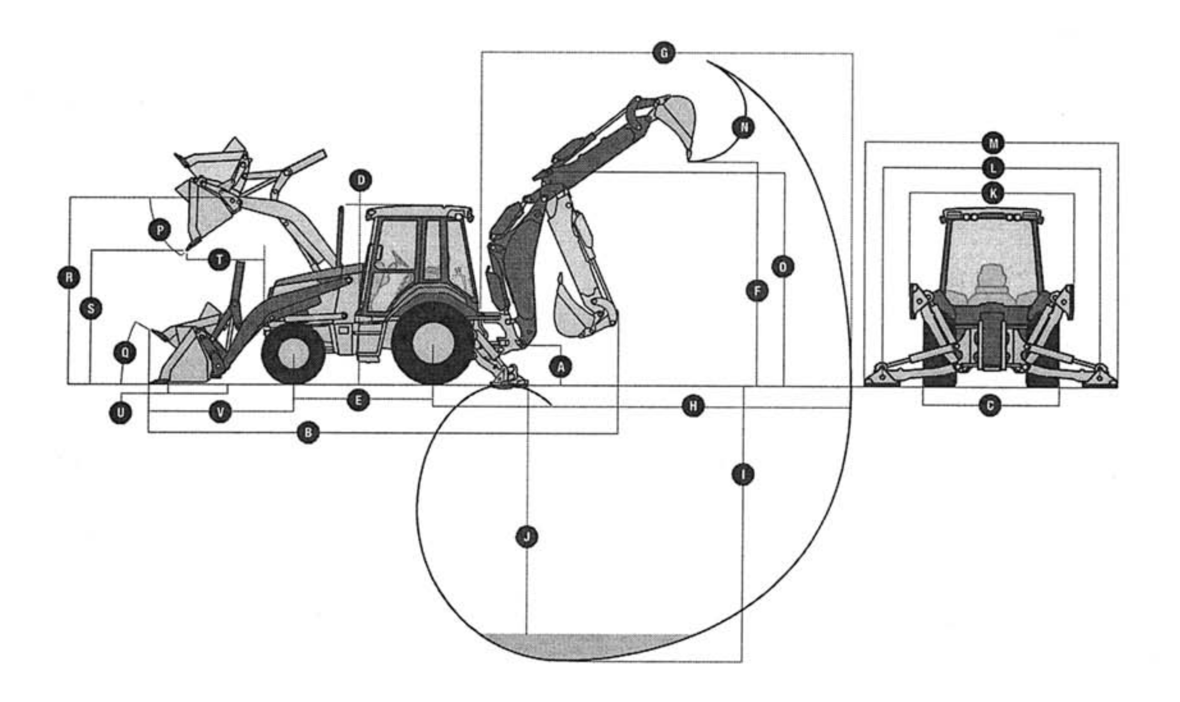
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1.5.1 Midsize Rubber Tire Backhoe

Model 310. A 92-hp midsize machine pictured with optional forklift attachment.

Overall Dimensions

A	Ground Clearance (minimum)	13 in. (330 mm)
B	Overall Length (transport)	23 ft. 6 in. (7.16 m)
C	Width over Tires	7 ft. 2 in. (2.18 m)
D	Height to Top of ROPS/Cab	9 ft. 2 in. (2.79 m)
E	Length from Axle to Axle	
	Non-Powered Front Axle	6 ft. 11 in. (2.11 m)
	Mechanical-Front-Wheel-Drive Axle	7 ft. 0 in. (2.14 m)



Backhoe Dimensions / Performance

Backhoe specifications are with 24-in. x 7.5-cu.-ft. (610 mm x 0.21 m³) bucket

Bucket Range	12–30 in. (305–762 mm)	
Digging Force		
Bucket Cylinder	15,236 lb. (67.8 kN)	
Crowd Cylinder	8,090 lb. (36.0 kN)	
Swing Arc	180 deg.	
Operator Control	two joysticks	
	With Extendable Dipperstick	
	Retracted	*Extended*
F Loading Height (truck loading position)	11 ft. 3 in. (3.43 m)	14 ft. 1 in. (4.29 m)
G Reach from Center of Swing Pivot	18 ft. 7 in. (5.66 m)	21 ft. 11 in. (6.68 m)
H Reach from Center of Rear Axle	22 ft. 1 in. (6.73 m)	25 ft. 4 in. (7.72 m)
I Digging Depth (SAE maximum)	14 ft. 11 in. (4.55 m)	18 ft. 5 in. (5.61 m)
J Digging Depth (SAE)		
2-ft. (610 mm) Flat Bottom	14 ft. 9 in. (4.50 m)	18 ft. 3 in. (5.56 m)
8-ft. (2440 mm) Flat Bottom	13 ft. 9 in. (4.19 m)	17 ft. 6 in. (5.33 m)
K Stabilizer Width (transport with ROPS)	7 ft. 2 in. (2.18 m)	7 ft. 2 in. (2.18 m)
L Stabilizer Spread (operating)		
Standard Stabilizers	10 ft. 2 in. (3.10 m)	10 ft. 2 in. (3.10 m)
Long Stabilizers	11 ft. 4 in. (3.45 m)	11 ft. 4 in. (3.45 m)
M Stabilizer Overall Width (operating)		
Standard Stabilizers	11 ft. 7 in. (3.53 m)	11 ft. 7 in. (3.53 m)
Long Stabilizers	13 ft. 3 in. (4.03 m)	13 ft. 3 in. (4.03 m)
N Bucket Rotation	190 deg.	190 deg.
O Transport Height	11 ft. 5 in. (3.48 m)	11 ft. 5 in. (3.48 m)

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1.5.1 Midsize Rubber Tire Backhoe (Continued)

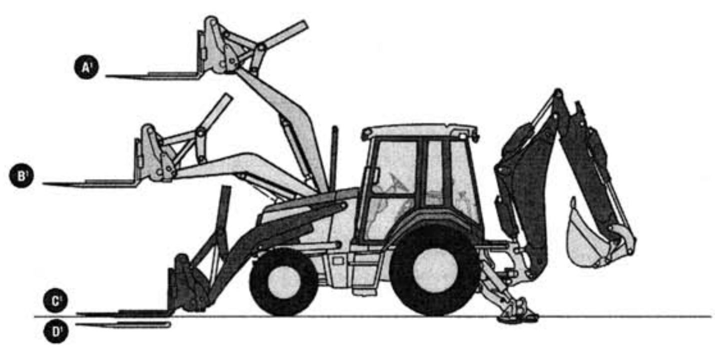
Loader Dimensions / Performance

(see page 4 for line art)

P Bucket Dump Angle (maximum)	45 deg.					
Q Rollback Angle at Ground Level	40 deg.					
	Heavy-duty	*Heavy-duty*	*Heavy-duty long lip*	*Heavy-duty*	*Multipurpose*	*Multipurpose*
Bucket Capacity	1.00 cu. yd. (0.77 m^3)	1.12 cu. yd. (0.86 m^3)	1.25 cu. yd. (0.96 m^3)	1.31 cu. yd. (1.00 m^3)	1.25 cu. yd. (0.96 m^3)	1.31 cu. yd. (1.00 m^3)
Width	86 in. (2184 mm)	86 in. (2184 mm)	86 in. (2184 mm)	92 in. (2337 mm)	86 in. (2184 mm)	92 in. (2337 mm)
R Height to Bucket Hinge Pin (maximum)	11 ft. 2 in. (3.40 m)	11 ft. 2 in. (3.40 m)	11 ft. 2 in. (3.40 m)	11 ft. 2 in. (3.40 m)	11 ft. 2 in. (3.40 m)	11 ft. 2 in. (3.40 m)
Standard Loader Option						
Weight	800 lb. (363 kg)	860 lb. (390 kg)	892 lb. (405 kg)	1,148 lb. (521 kg)	1,750 lb. (795 kg)	1,800 lb. (817 kg)
Breakout Force	11,160 lb. (49.6 kN)	11,051 lb. (49.2 kN)	10,210 lb. (45.4 kN)	10,300 lb. (45.8 kN)	9,700 lb. (43.1 kN)	9,650 lb. (42.9 kN)
Lift Capacity (full height)	7,419 lb. (3368 kg)	7,353 lb. (3338 kg)	7,340 lb. (3332 kg)	7,200 lb. (3269 kg)	6,700 lb. (3042 kg)	6,600 lb. (2996 kg)
S Dump Clearance (bucket at 45 deg.)	8 ft. 10 in. (2.69 m)	8 ft. 10 in. (2.69 m)	8 ft. 2 in. (2.48 m)	8 ft. 8 in. (2.64 m)	8 ft. 7 in. (2.62 m)	8 ft. 7 in. (2.62 m)
T Reach at Full Height (bucket at 45 deg.)	30.9 in. (785 mm)	30.2 in. (767 mm)	35.9 in. (911 mm)	30.1 in. (765 mm)	32.2 in. (818 mm)	32.2 in. (818 mm)
U Digging Depth Below Ground (bucket level)	6.3 in. (160 mm)	6.9 in. (175 mm)	5.8 in. (147 mm)	8.1 in. (206 mm)	7.3 in. (185 mm)	7.3 in. (185 mm)
V Length From Front Axle Centerline to Bucket Cutting Edge	6 ft. 8 in. (2.03 m)	6 ft. 8 in. (2.03 m)	7 ft. 2 in. (2.18 m)	6 ft. 8 in. (2.03 m)	7 ft. 3 in. (2.20 m)	7 ft. 1 in. (2.15 m)
Tool-Carrier Loader Option						
Weight	835 lb. (379 kg)	873 lb. (396 kg)	860 lb. (390 kg)	1,085 lb. (493 kg)	1,687 lb. (766 kg)	1,737 lb. (789 kg)
Breakout Force	11,287 lb. (50.2 kN)	11,900 lb. (52.9 kN)	10,300 lb. (45.8 kN)	11,450 lb. (50.9 kN)	9,740 lb. (43.3 kN)	9,680 lb. (43.1 kN)
Lift Capacity (full height)	7,026 lb. (3190 kg)	7,200 lb. (3269 kg)	6,625 lb. (3008 kg)	7,215 lb. (3276 kg)	5,950 lb. (2701 kg)	5,850 lb. (2656 kg)
S Dump Clearance (bucket at 45 deg.)	8 ft. 6 in. (2.58 m)	8 ft. 7 in. (2.61 m)	8 ft. 3 in. (2.51 m)	8 ft. 6 in. (2.59 m)	8 ft. 2 in. (2.50 m)	8 ft. 2 in. (2.50 m)
T Reach at Full Height (bucket at 45 deg.)	30.6 in. (777 mm)	29.3 in. (744 mm)	34.2 in. (868 mm)	30.0 in. (762 mm)	32.9 in. (836 mm)	32.9 in. (836 mm)
U Digging Depth Below Ground (bucket level)	5.5 in. (140 mm)	5.5 in. (140 mm)	4.8 in. (122 mm)	5.5 in. (140 mm)	6.0 in. (152 mm)	6.0 in. (152 mm)
V Length From Front Axle Centerline to Bucket Cutting Edge	7 ft. 1 in. (2.15 m)	7 ft. 1 in. (2.15 m)	7 ft. 7 in. (2.30 m)	7 ft. 1 in. (2.15 m)	7 ft. 7 in. (2.32 m)	7 ft. 5 in. (2.27 m)

Lift Capacity with Quick-Coupler / Forks

A' Maximum Height	4,875 lb. (2211 kg)
B' Maximum Reach	7,580 lb. (3438 kg)
C' At Ground Line	9,700 lb. (4400 kg)
D' Below Ground Line	8.3 in. (211 mm)



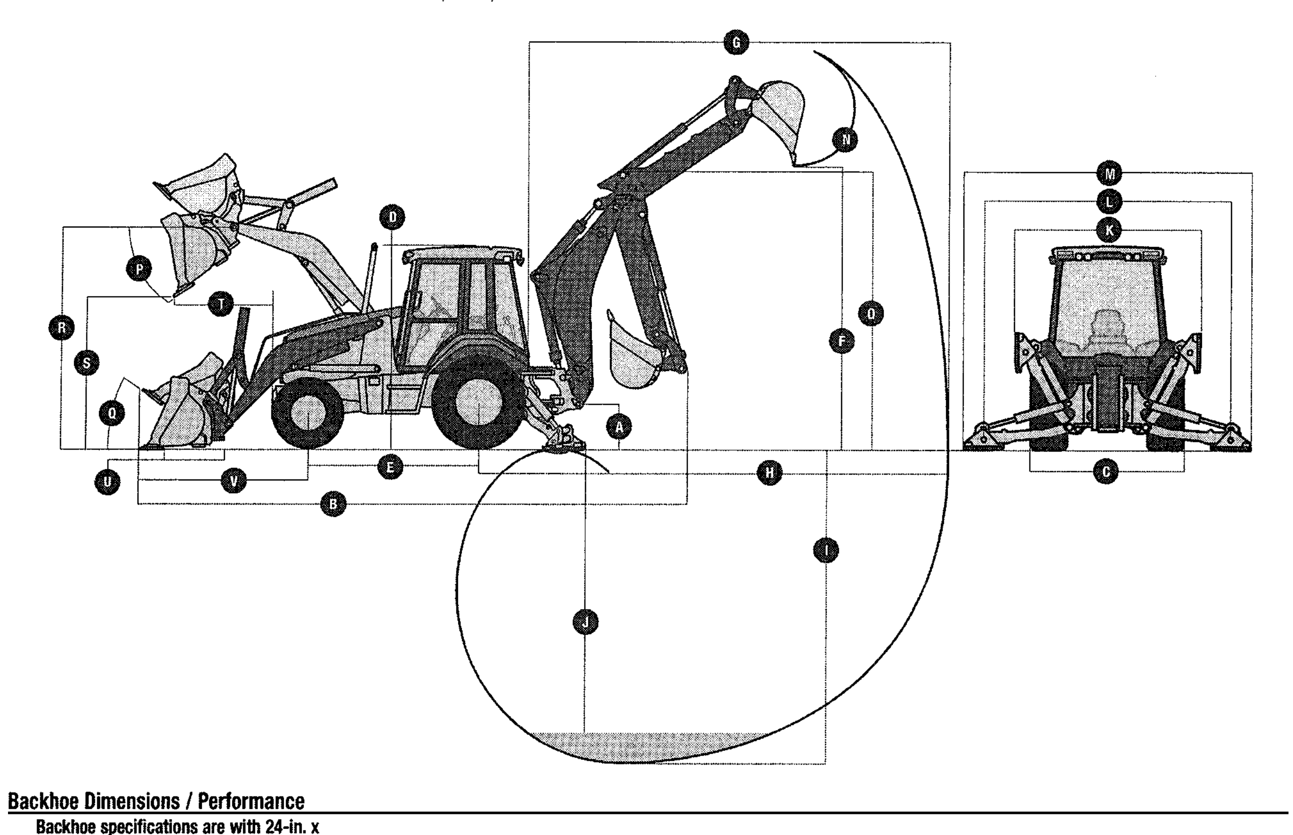
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1.5.2 Large-Capacity Backhoe

Deere's large-capacity backhoe, model 710J, with 123-hp turbocharged engine.

Overall Dimensions

A	Ground Clearance (minimum)	14 in. (356 mm)
B	Overall Length (transport)	26 ft. 9 in. (8.15 m)
C	Width over Tires	7 ft. 6 in. (2.29 m)
D	Height to Top of ROPS/Cab	9 ft. 9 in. (2.97 m)
E	Length from Axle to Axle	
	Non-Powered Front Axle	8 ft. 3 in. (2.52 m)
	Mechanical-Front-Wheel-Drive Axle	8 ft. 2 in. (2.49 m)



Backhoe Dimensions / Performance

Backhoe specifications are with 24-in. x 11.1-cu.-ft. (610 mm x 0.31 m³) bucket

Bucket Range		24–36 in. (610–914 mm)
Digging Force		
	Bucket Cylinder	17,000 lb. (75.6 kN)
	Crowd Cylinder	11,750 lb. (52.3 kN)
Swing Arc		180 deg.
Operator Control		pilot control

		With Standard Backhoe	*With Optional Extendable Dipperstick Retracted*	*Extended*
F	Loading Height (truck loading position)	14 ft. 3 in. (4.34 m)	14 ft. 3 in. (4.34 m)	17 ft. 0 in. (5.18 m)
G	Reach from Center of Swing Pivot	22 ft. 6 in. (6.86 m)	22 ft. 6 in. (6.86 m)	26 ft. 10 in. (8.19 m)
H	Reach from Center of Rear Axle	26 ft. 8 in. (8.13 m)	26 ft. 8 in. (8.13 m)	31 ft. 0 in. (9.46 m)
I	Digging Depth (SAE maximum)	17 ft. 10 in. (5.44 m)	17 ft. 10 in. (5.44 m)	22 ft. 4 in. (6.81 m)
J	Digging Depth (SAE)			
	2-ft. (610 mm) Flat Bottom	17 ft. 9 in. (5.41 m)	17 ft. 9 in. (5.41 m)	22 ft. 5 in. (6.83 m)
	8-ft. (2440 mm) Flat Bottom	17 ft. 0 in. (5.18 m)	17 ft. 0 in. (5.18 m)	21 ft. 7 in. (6.58 m)
K	Stabilizer Width (transport with ROPS)	7 ft. 11 in. (2.41 m)	7 ft. 11 in. (2.41 m)	7 ft. 11 in. (2.41 m)
L	Stabilizer Spread (operating)	13 ft. 1 in. (3.99 m)	13 ft. 1 in. (3.99 m)	13 ft. 1 in. (3.99 m)
M	Stabilizer Overall Width (operating)	15 ft. 3 in. (4.65 m)	15 ft. 3 in. (4.65 m)	15 ft. 3 in. (4.65 m)
N	Bucket Rotation	190 deg.	190 deg.	190 deg.
O	Transport Height	13 ft. 8 in. (4.17 m)	13 ft. 10 in. (4.22 m)	13 ft. 10 in. (4.22 m)

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1.6.0 Loaders—Compact Rubber Tire

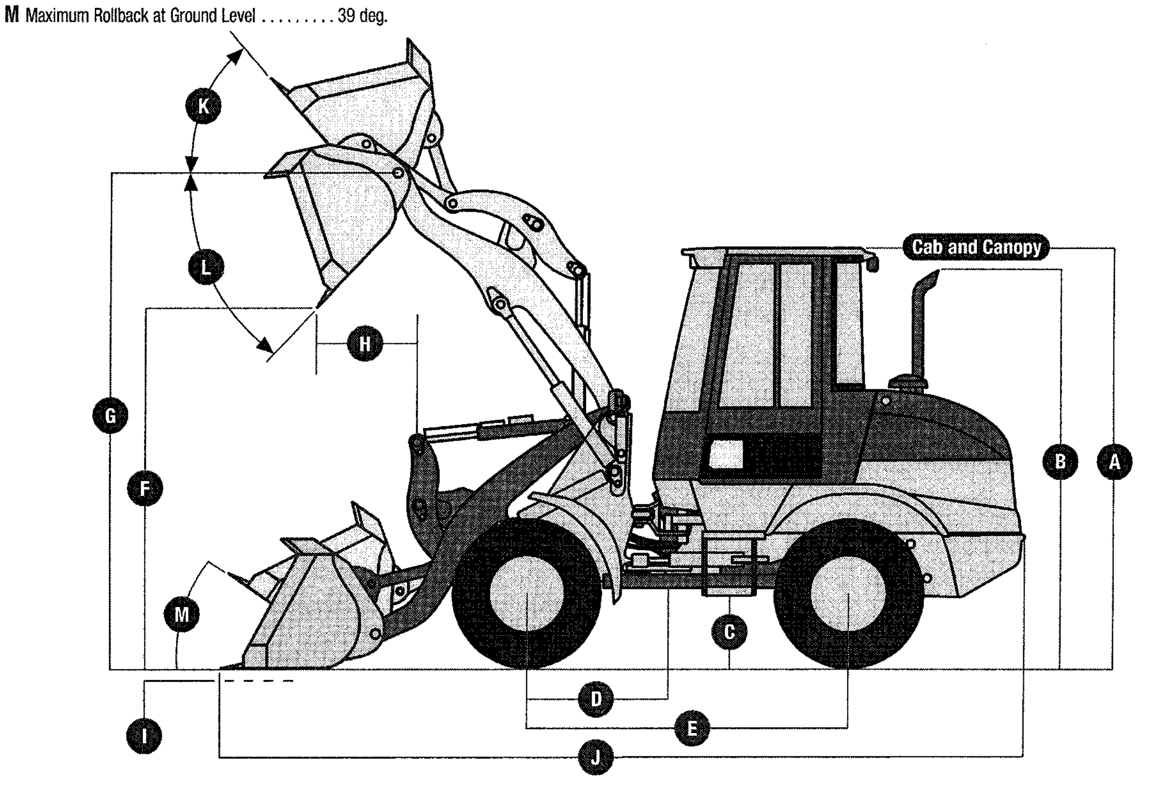
with 1.0 yd^3 (0.7646 m^3) bucket.

Hydraulic System/Steering

Pump (loader and steering) .... fixed-displacement gear pump; open-center system
Maximum Flow @ 2,800 rpm .... 17 gpm (64.4 L/min.) @ 1,000 psi (6895 kPa)
System Relief Pressure
Loader .... 3,190 psi (22 000 kPa)
Steering .... 2,611 psi (18 000 kPa)
Loader Controls .... pilot-operated three-function valve with single-lever control for boom and bucket, and auxiliary lever for standard pin disconnect and auxiliary hydraulics, with control-lever lockout feature; optional additional four-function valve with push-button control
Steering (conforms to SAE J1511)
Type .... power, fully hydraulic
Articulation Angle/Rear Wheel Steering
Angle .... 56-deg. arc (28 deg. each direction), plus 26 deg. rear wheel steering tied mechanically to articulation; equivalent of 97-deg. conventional steering system articulation
Hydraulic Cycle Times
Raise................................ 4.9 sec.
Dump .... 1.4 sec.
Lower .... 4.0 sec. (float down) / 3.6 sec. (power down)
Total .... 9.9 sec.
Maximum Lift Capacity *with 1.0-cu.-yd. (0.8 m^3) bucket with bolt-on edge*
Lift at Ground Level..................... 9,892 lb. (4487 kg)
Lift at Maximum Height................. 6,407 lb. (2906 kg)
Turning Radius (measured to centerline of outside tire)........................... 11 ft. 6 in. (3505 mm)

Dimensions with Quick-Coupler/Bucket

A Height to Top of Cab and Canopy .... 8 ft. 11 in. (2725 mm)
B Height to Top of Exhaust.................. 8 ft. 6 in. (2600 mm)
C Ground Clearance....................... 11.6 in. (295 mm)
D Length from Center of Front Axle .... 29.5 in. (750 mm)
E Wheelbase .... 84.6 in. (2150 mm)
F Dump Clearance........................ ▲ (see page 4)
G Height to Hinge Pin, Fully Raised .... 10 ft. 6.4 in. (3211 mm)
H Dump Reach at Full Height................ ▲▲ (see page 4)
I Maximum Digging Depth .... 3.1 in. (80 mm)
J Overall Length .... ▲▲▲ (see page 4)
K Maximum Rollback at Full Height........... 52 deg.
L Bucket Dump at Full Height .... 42 deg.
M Maximum Rollback at Ground Level .... 39 deg.



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1.6.1 Loaders—Mid-capacity Rubber Tire

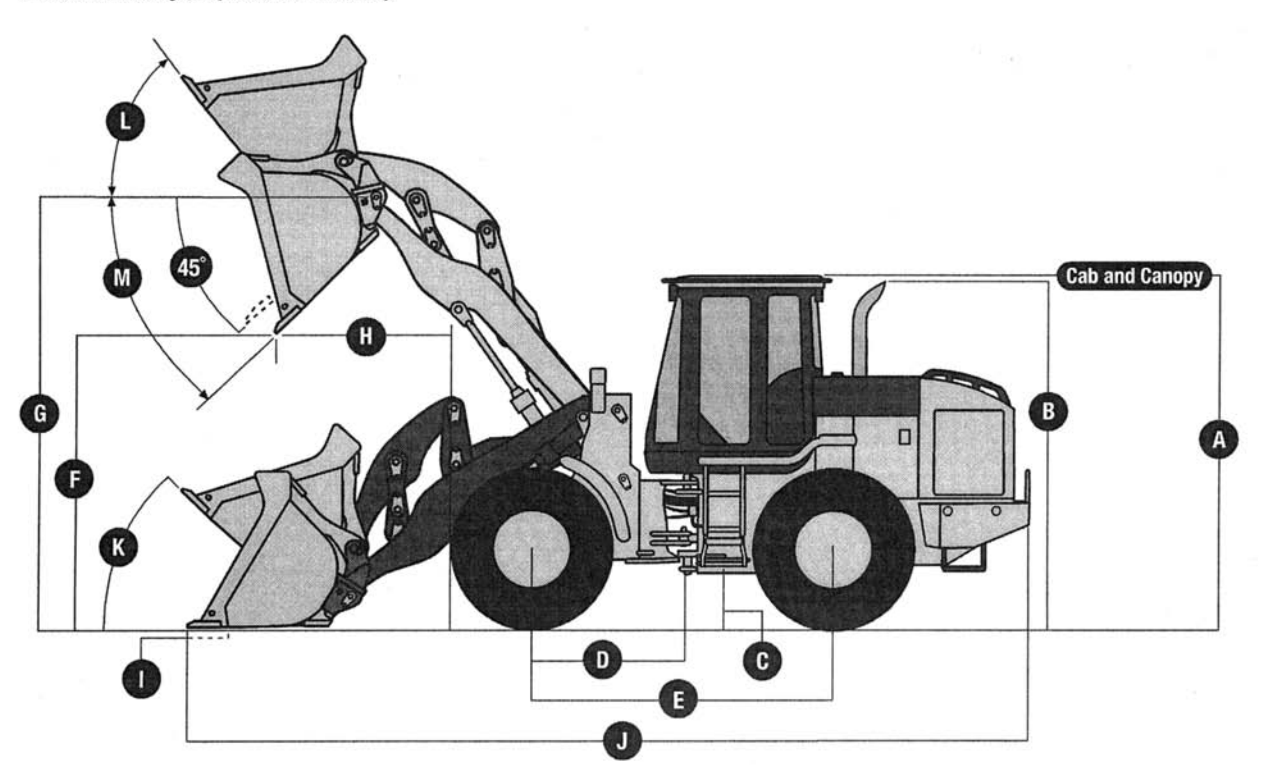
Loader with 2.5 yd^3 (1.9 m^3) bucket.

Hydraulic System/Steering

Pump (loader and steering)	variable-displacement, axial-piston pump; closed-center, pressure-compensating system
Maximum Rated Flow	37 gpm (140 L/m) @ 1,000 psi (6895 kPa)
System Relief Pressure (loader and steering)	3,600 psi (24 821 kPa)
Loader Controls	two-function valve; single- or dual-lever controls; control lever lockout feature; optional third- and fourth-function valve with auxiliary lever
Steering (conforms to SAE J1511)	
Type	power, fully hydraulic
Articulation Angle	80-deg. arc (40 deg. each direction)
Hydraulic Cycle Times	
Raise	5.5 sec.
Dump	1.1 sec.
Lower (float down)	1.9 sec.
Total	8.5 sec.
Maximum Lift Capacity	*with 2.0-cu.-yd. (1.5 m^3) general-purpose bucket with bolt-on edge*
Lift at Ground Level	23,412 lb. (10 620 kg)
Turning Radius (measured to centerline of outside tire)	15 ft. 5 in. (4.70 m)

Dimensions with Quick-Coupler and Hook-On Bucket

A Height to Top of Cab and Canopy	10 ft. 5 in. (3.15 m)
B Height to Top of Exhaust	10 ft. 4 in. (3.14 m)
C Ground Clearance	15.6 in. (396 mm)
D Length from Centerline to Front Axle	4 ft. 6 in. (1.38 m)
E Wheelbase	9 ft. 0 in. (2.75 m)
F Dump Clearance	(see page 4
G Height to Hinge Pin, Fully Raised	12 ft. 0 in. (3.66 m)
H Dump Reach	(see page 4)
I Maximum Digging Depth	4.8 in. (122 mm)
J Overall Length	(see page 4)
K Maximum Rollback at Ground Level	41 deg.
L Maximum Rollback, Boom Fully Raised	48 deg.
M Maximum Bucket Angle, Fully Raised	50 deg.



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1.6.2 Loaders—Large-Capacity Rubber Tire

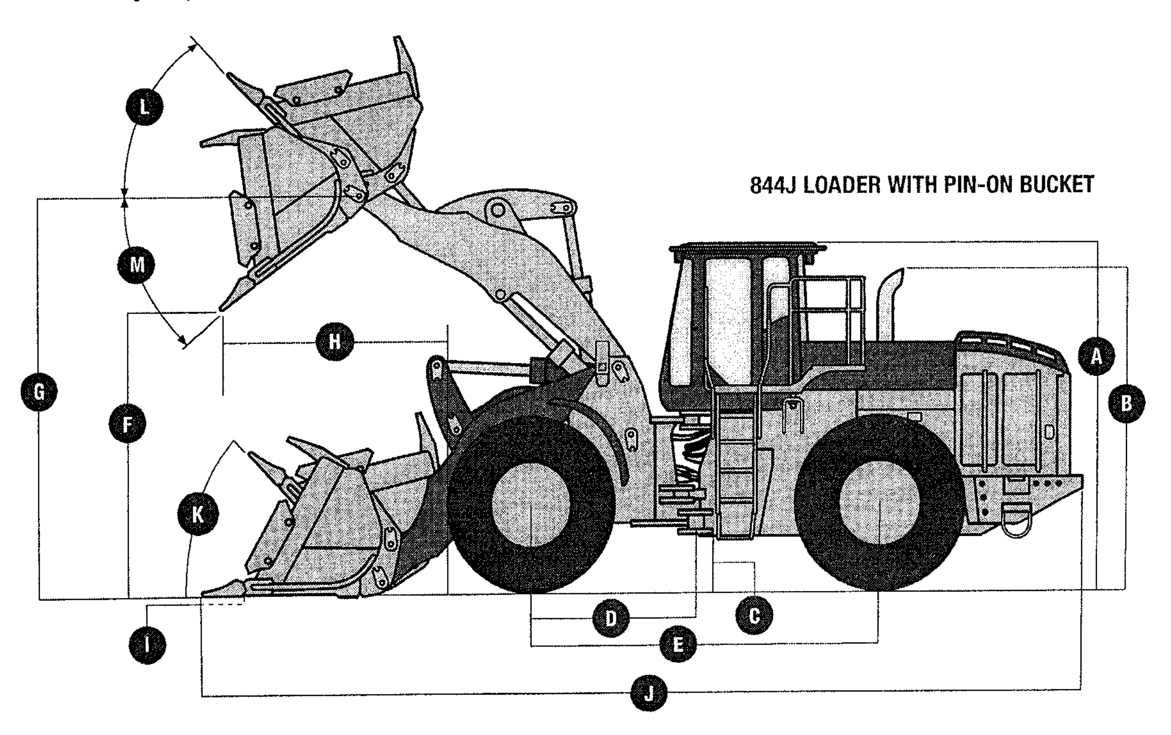
Loader with 6 yd^3 (4.7 m^3) bucket.

Hydraulic System/Steering

Pump (loader and steering)	three variable-displacement, load-sensing axial piston pumps; closed-center system
Maximum Flow @ 2,250 rpm	169 gpm (640 L/min.) @ 1,000 psi (6900 kPa)
System Relief Pressure (loader and steering)	loader and steering 3,500 psi (24 132 kPa)
Loader Controls	two-function valve; single- and dual-lever controls; control lever lockout feature; optional third-function valve with auxiliary lever
Steering (conforms to SAE J1511)	
Type	power, fully hydraulic
Articulation Angle	80-deg. arc (40 deg. each direction)
Hydraulic Cycle Times	*Standard Z-Bar*
Raise	5.9 sec.
Dump	1.9 sec.
Lower (float)	3.5 sec.
Total	11.3 sec.
Maximum Lift Capacity	*with 7.25-cu.-yd. (5.5 m^3) general-purpose bucket with bolt-on cutting edge*
Lift at Ground Level	69,020 lb. (31 300 kg)
Lift at Maximum Height	27,550 lb. (12 490 kg)
Turning Radius (measured to centerline of outside tire)	20 ft. 8 in. (6303 mm)

Dimensions with Pin-On Bucket

	Standard Z-Bar
A Height to Top of Cab	12 ft. 4 in. (3748 mm)
B Height to Top of Exhaust	11 ft. 8 in. (3549 mm)
C Ground Clearance	17.8 in. (452 mm)
D Length from Centerline to Front Axle	73 in. (1850 mm)
E Wheelbase	146 in. (3700 mm)
F Dump Clearance	▲ (see page 4)
G Height to Hinge Pin, Fully Raised	15 ft. 1 in. (4608 mm)
H Dump Reach	▲▲ (see page 4)
I Maximum Digging Depth	4.9 in. (125 mm)
J Overall Length	▲▲▲ (see page 4)
K Maximum Rollback at Ground Level	40 deg.
L Maximum Rollback, Boom Fully Raised	60 deg.
M Maximum Bucket Angle, Fully Raised	45 deg.



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1.6.3 Loaders—Mid-Capacity Tracked Machine

Model 605C, with a 1.7 yd^3 (1.3 m^3) bucket.

Optional or Special Equipment

Add (+) or deduct (–) lb. (kg) as indicated to base weight for units with

18-in. (457 mm) Track Shoes .... included in base unit
20-in. (508 mm) Track Shoes .... 194 lb. (88 kg)
Additional Front Lights (2) (cab only) .... 26 lb. (12 kg)
Bolt-On Rock Guards..................... 260 lb. (118 kg)
Cab with Air Conditioning .... 1,358 lb. (616 kg)
Heavy-Duty Rear Bumper✱ .... 476 lb. (216 kg)
Hydraulic Controls for Front Attachment ...... included with multipurpose bucket
Multipurpose Bucket with Bolt-On Teeth ...... 794 lb. (360 kg)
Rear Counterweight† .... 230 lb. (106 kg)
ROPS Canopy (less cab) .... included in base unit
Segmented Cutting Edges................. 176 lb. (80 kg)
✱Included in base unit. / †Included in canopy base unit.

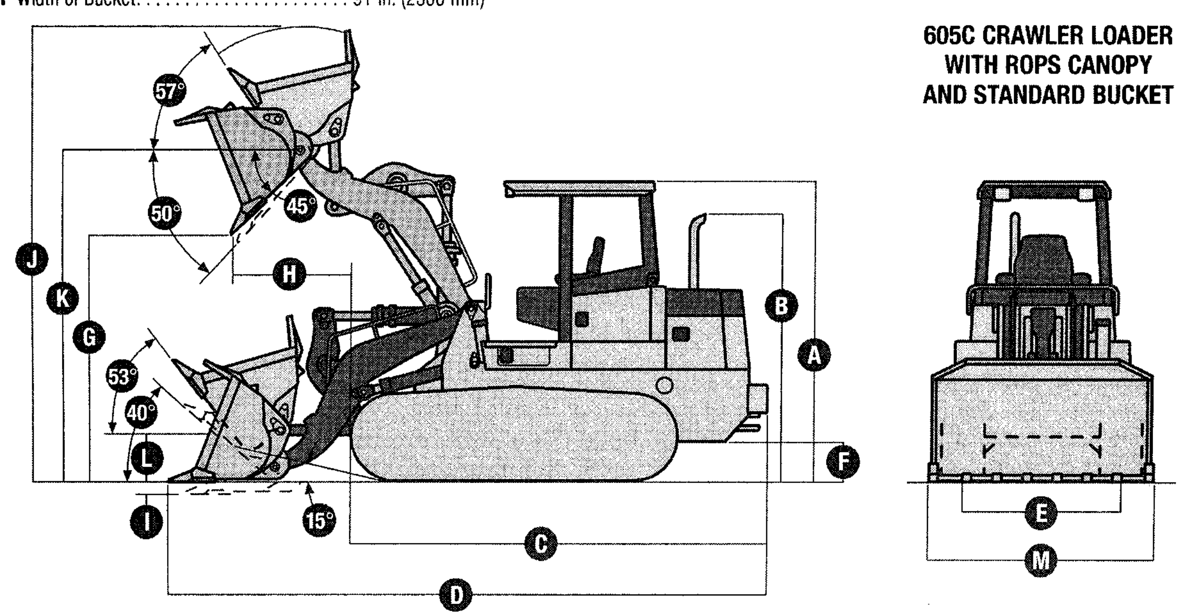
Dimensions

Rounded to the nearest whole number.

A Height over Canopy (including grousers) . . . 118 in. (2998 mm)
B Height over Exhaust Pipe............... 90 in. (2276 mm)
C Length to Front of Track .... 152 in. (3859 mm)
D Overall Length (with standard bucket with bolt-on teeth).................... 212 in. (5383 mm)
E Track Gauge .... 63 in. (1600 mm)
F Ground Clearance .... 16 in. (408 mm)

Standard Bucket with Bolt-on Teeth and Segmented Cutting Edges

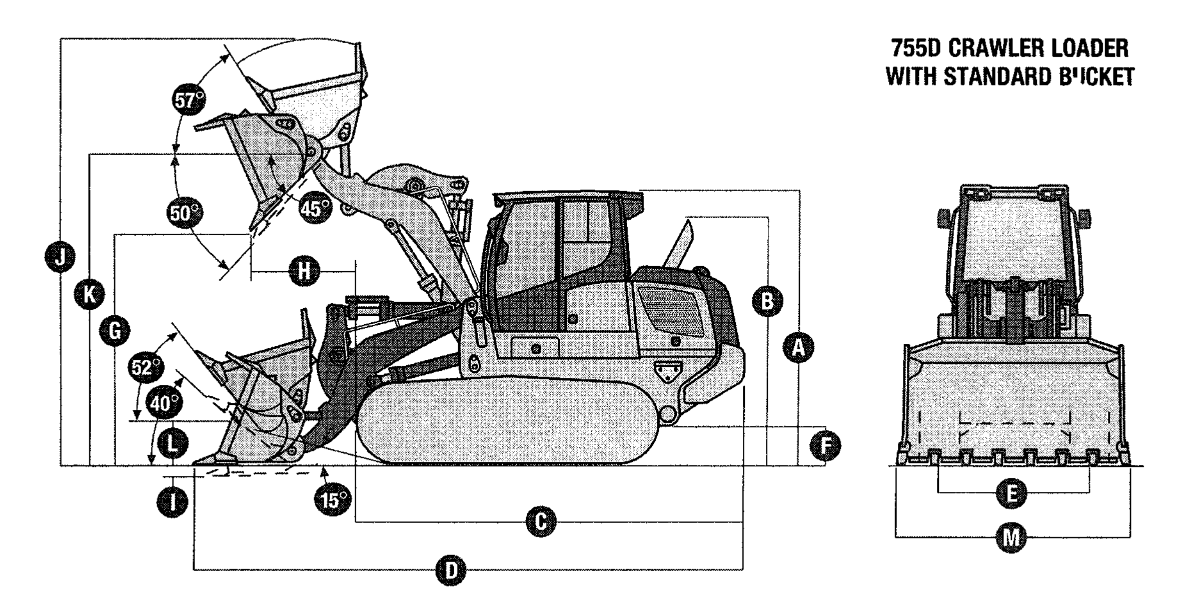
Capacity Heaped........................ 1.7 cu. yd. (1.3 m^3)
Breakout Force .... 22,480 lb. (10 200 kg)
Static Tipping Load .... 14,750 lb. (6690 kg)
G Dumping Height at 45 Degrees.......... 105 in. (2679 mm)
H Reach at 45 Degrees.................. 35 in. (890 mm)
I Maximum Digging Depth Below Grade .... 5.1 in. (130 mm)
J Maximum Operating Height............. 176 in. (4474 mm)
K Maximum Height of Hinge Pin........... 133 in. (3368 mm)
L Height of Hinge Pin, Transport Position .... 18.1 in. (459 mm)
M Width of Bucket...................... 91 in. (2300 mm)



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1.6.4 Loaders—Large-Capacity Tracked Machine

Model 755D, with a 3.14 yd^3 (3.31 m^3) bucket.



Machine Dimensions

Cab

A	Overall Height (cab with grousers)	10 ft. 10 in. (3.31 m)
B	Height Over Exhaust Pipe	9 ft. 8 in. (2.95 m)
C	Length to Front of Track	16 ft. 0 in. (4.87 m)
D	Overall Length (with bucket)	22 ft. 6 in. (6.85 m)
E	Track Gauge	5 ft. 11 in. (1.80 m)
F	Ground Clearance	18 in. (458 mm)
	Machine Width with 20-in. (508 mm) Shoes	7 ft. 7 in. (2.31 m)

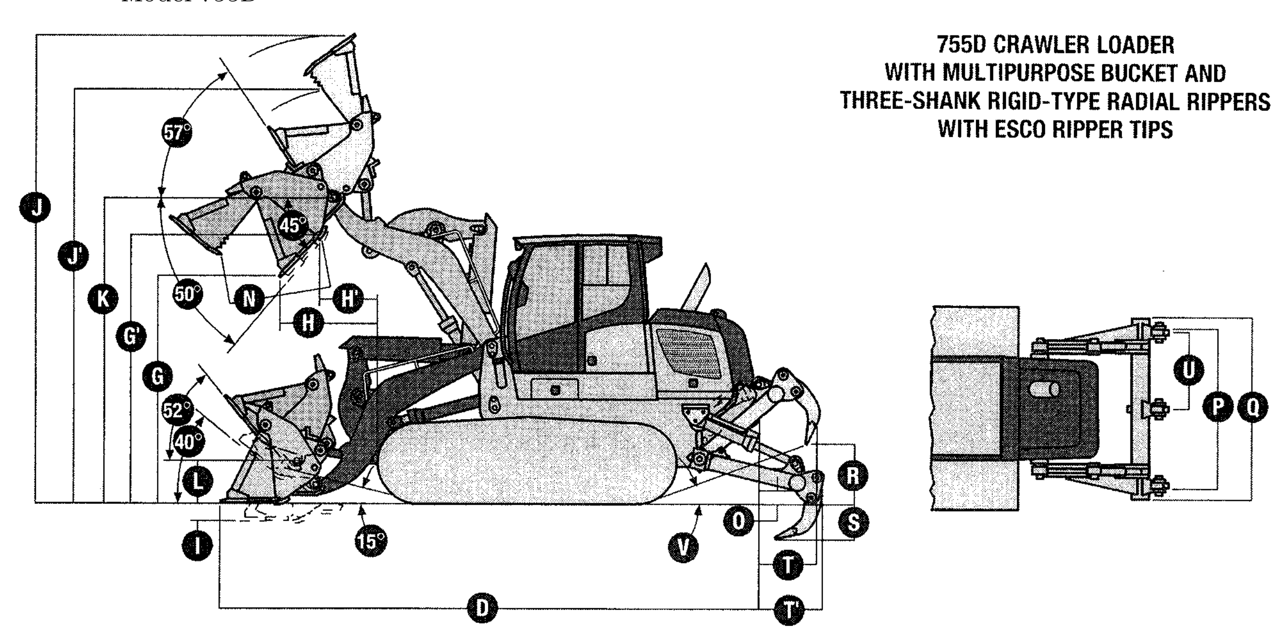
Standard Bucket with Bolt-On Teeth

	Capacity Heaped	3.14 cu. yd. (2.4 m^3)
	Breakout Force (ISO8313)	36,869 lb. (164 kN)
	Static Tipping Load (ISO8313)	31,597 lb. (14 332 kg)
	Bucket Weight	3,757 lb. (1704 kg)
G	Dumping Height at 45 deg. (ISO7131)	9 ft. 9 in. (2.98 m)
H	Reach at 45 deg.	4 ft. 0 in. (1.21 m)
I	Maximum Digging Depth Below Grade	6 in. (150 mm)
J	Maximum Operating Height (bucket at full lift)	18 ft. 1 in. (5.50 m)
K	Maximum Height at Hinge Pin	13 ft. 4 in. (4.05 m)
L	Height at Hinge Pin (transport position)	23 in. (576 mm)
M	Width of Bucket	8 ft. 4 in. (2.53 m)

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1.6.4.1 Loaders—2.62 yd^3 (2.0 m^3) Bucket and Rear Ripper

Model 755D



Multipurpose Bucket with Bolt-On Teeth

	Capacity Heaped	2.62 cu. yd. (2.0 m^3)
	Breakout Force (ISO8313)	34,845 lb. (155 kN)
	Static Tipping Load (ISO8313)	28,989 lb. (13 149 kg)
	Bucket Weight	4,954 lb. (2247 kg)
D	Overall Length (with bucket)	23 ft. 1 in. (7.04 m)
G	Dumping Height at 45 deg. (ISO7131) — Bucket	9 ft. 9 in. (2.98 m)
G'	Dumping Height at 45 deg. (ISO7131) — Blade	11 ft. 9 in. (3.58 m)
H	Reach at 45 deg. — Bucket	4 ft. 0 in. (1.20 m)
H'	Reach at 45 deg. — Blade	2 ft. 2 in. (661 mm)
I	Maximum Digging Depth Below Grade	8.66 in. (220 mm)
J	Maximum Operating Height (bucket at full lift) — Bucket Open	20 ft. 3 in. (6.16 m)
J'	Maximum Operating Height (bucket at full lift) — Bucket Closed	18 ft. 0 in. (5.46 m)
K	Maximum Height at Hinge Pin	13 ft. 4 in. (4.05 m)
L	Height at Hinge Pin (transport position)	23 in. (576 mm)
N	Width of Opening	4 ft. 3 in. (1.29 m)

Rear Ripper

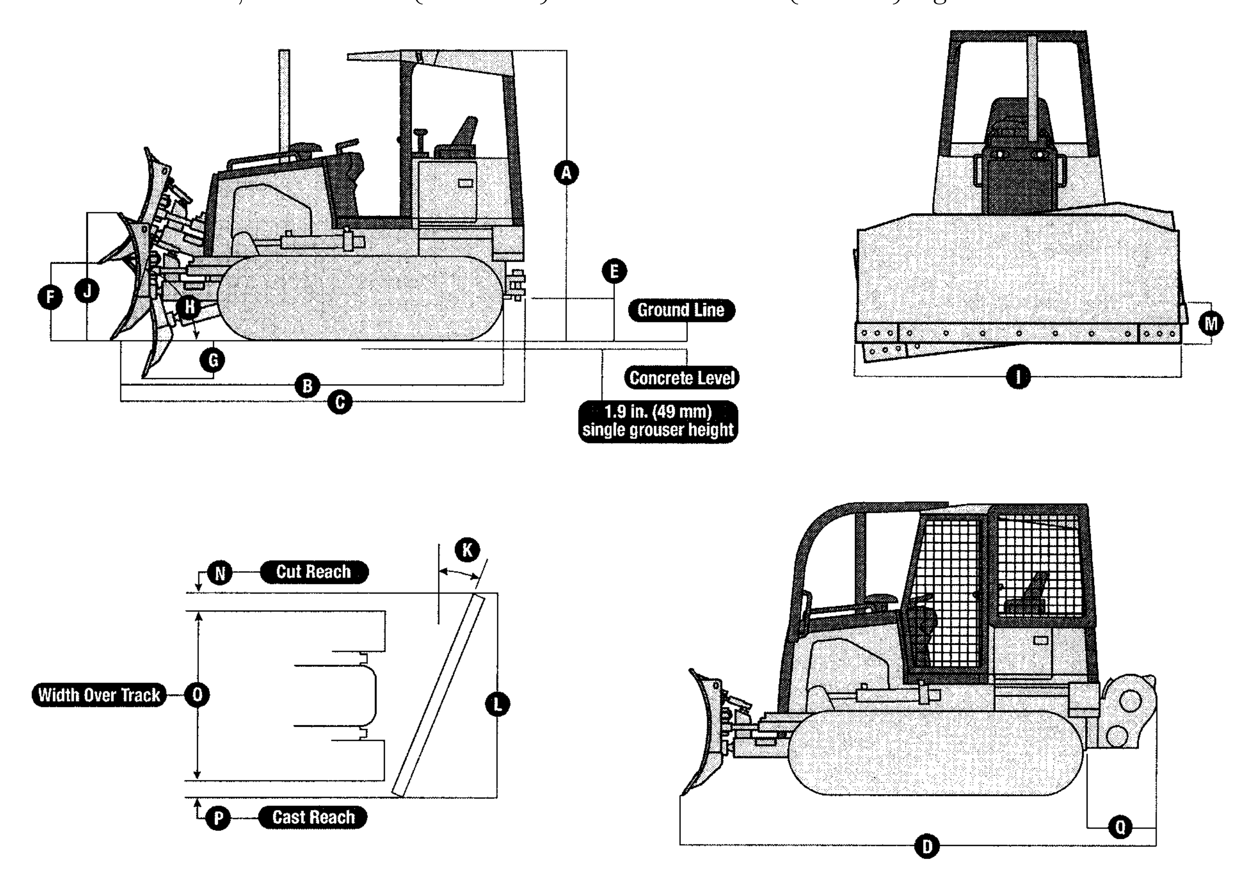
Three-shank rigid-type radial ripper with ESCO ripper tips

	Weight	2,590 lb. (1175 kg)
O	Ground Clearance Below Toolbar	33 in. (826 mm)
P	Ripping Width	6 ft. 5 in. (1.96 m)
Q	Toolbar Width	7 ft. 0 in. (2.10 m)
R	Lifting Height	33 in. (826 mm)
S	Ripping Depth	15 in. (390 mm)
T	Additional Length Overall — Raised	29 in. (740 mm)
T'	Additional Length Overall — Transport	30 in. (760 mm)
U	Distance between Teeth	35 in. (900 mm)
V	Approach Angle (ripper raised)	20 deg.

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1.7.0 Small Dozer

Model 450J, with a 96-in.- (2464-mm-) wide and 3-ft 2-in.- (955-mm) high blade.



Machine Dimensions	450J LT	450J LGP
A Overall Height (ROPS or cab)	9 ft. 0 in. (2.74 m)	9 ft. 0 in. (2.74 m)
Height of Grousers	1.9 in. (48.3 mm)	1.9 in. (48 mm)
B Overall Length	12 ft. 11 in. (3.94 m)	13 ft. 2 in. (4013 mm)
C Overall Length with Extended Drawbar	13 ft. 6 in. (4.11 m)	13 ft. 4 in. (4064 mm)
D Overall Length with Winch	14 ft. 9 in. (4.50 m)	14 ft. 9 in. (4496 mm)
E Minimum Ground Clearance	13.6 in. (345 mm)	13.6 in. (345 mm)
F Blade Lift Height	30.4 in. (772 mm)	30.4 in. (772 mm)
G Blade Digging Depth	20.8 in. (528 mm)	20.8 in. (528 mm)
H Blade Cutting Edge Angle, Adjustable	52 to 60 deg.	52 to 60 deg.

Forestry Application — **450J LT / 450J LGP**

Available limb risers and screens for the rollover protective structure, John Deere-built, self-contained 4000S Winch* for versatile skidding and clearing operations

D	Overall Length with Winch**	14 ft. 9 in. (4496 mm)
Q	4000S Winch Length	30 in. (752 mm)

*Reference 4000S Winch spec sheet.
**See above for related dimensions.

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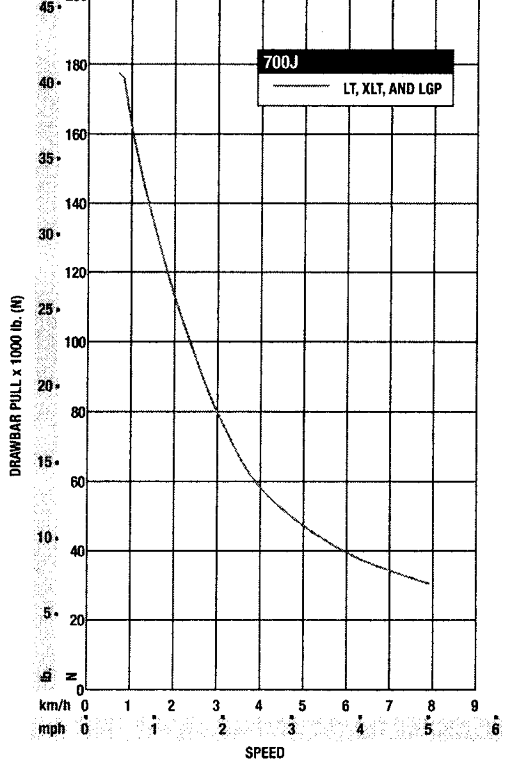
1.7.1 Medium-Size Dozer

Model 700 series, with a 120-in.- (3048-mm-) wide and a 39-in.- (991-mm-) high blade.

	Blade Specs	700J LT	700J XLT	700J LGP
I	Width	120 in. (3048 mm)	120 in. (3048 mm)	132 in. (3353 mm)
J	Height	39 in. (991 mm)	39 in. (991 mm)	39 in. (991 mm)
	SAE Capacity	3.44 cu. yd. (2.63 m³)	3.44 cu. yd. (2.63 m³)	3.75 cu. yd. (2.87 m³)
K	Blade Angle	25 deg.	25 deg.	25 deg.
L	Angled Width	109 in. (2769 mm)	109 in. (2769 mm)	121 in. (3073 mm)
M	Tilt	17 in. (432 mm)	17 in. (432 mm)	18 in. (457 mm)
N	Cut Reach	2 in. (51 mm)	1 in. (25 mm)	– 1 in. (– 25 mm)
O	Width Over Track	90 in. (2286 mm)	92 in. (2337 mm)	108 in. (2743 mm)
P	Cast Reach	16 in. (406 mm)	15 in. (381 mm)	13 in. (330 mm)
Q	4000S Winch Length	30.5 in. (775 mm)	30.5 in. (775 mm)	30.5 in. (775 mm)

	Rear Ripper	700J LT / 700J XLT / 700J LGP
	Weight	3,183 lb. (1444 kg)
R	Maximum Penetration	22.2 in. (563 mm)
S	Maximum Clearance Under Tip	23 in. (584 mm)
T	Overall Length (lowered position)	58.8 in. (1494 mm)
T'	Overall Length (raised position)	47.6 in. (1210 mm)
U	Overall Beam Width	76 in. (1930 mm)
V	Slope Angle (full raise)	26 deg.
W	Ripping Width	65.9 in. (1673 mm)
X	Distance Between Shanks (3 installed)	31.7 in. (806 mm)
	Distance Between Holes In Shank	4.1 in. (105 mm)

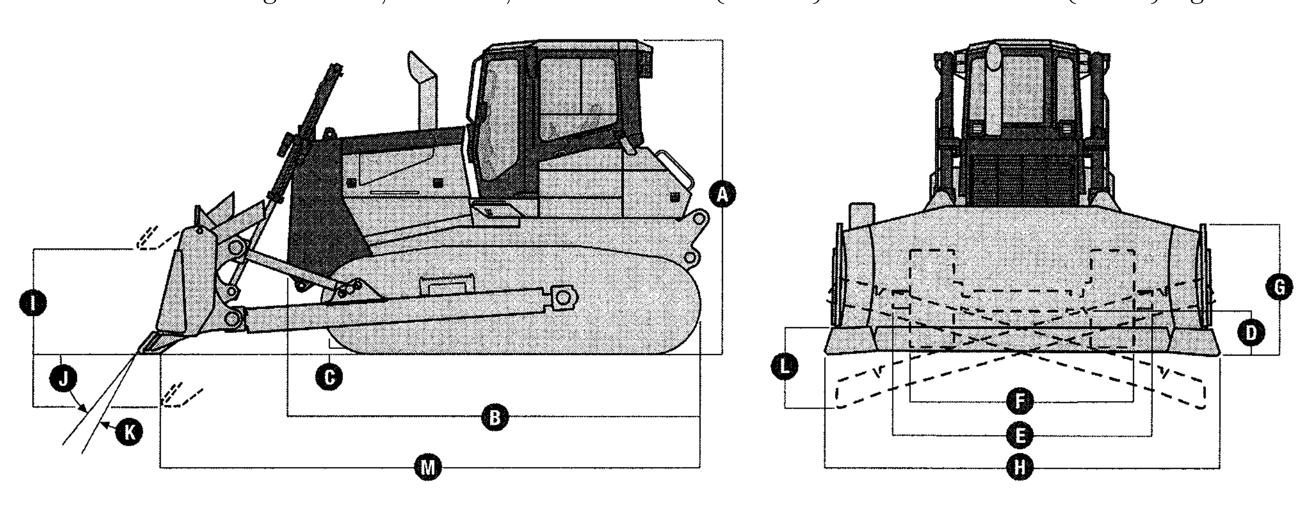
Drawbar Pull	
Crawler Speed vs Ground Pull	usable pull will depend on traction and weight of tractor



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1.7.2 Large Dozer

Deere's largest dozer, the 1050J, with a 13-ft 3-in. (4.04-m-) wide and a 5-ft 5-in. (1.7-m-) high blade.



Machine Dimensions

A	Overall Height Over Cab	11 ft. 11 in. (3.63 m)
B	Overall Length (without blade)	16 ft. 0 in. (4.88 m)
C	Height of Grousers	3 in. (84 mm)
D	Ground Clearance	25 in. (635 mm)
E	Total Width Over Blade-Mounting Trunnions	10 ft. 4 in. (3.15 m)
F	Overall Width with Extreme-Duty Single-Bar Grouser Shoes	
	22 in. (560 mm)	9 ft. 0 in. (2.74 m)
	24 in. (610 mm)	9 ft. 2 in. (2.79 m)
	26 in. (660 mm)	9 ft. 4 in. (2.84 m)
	28 in. (710 mm)	9 ft. 6 in. (2.90 m)

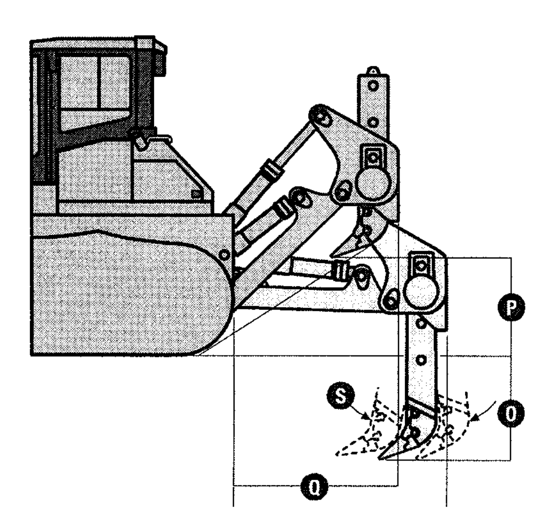
Blade Specs

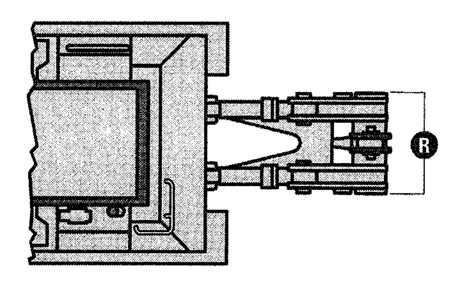
		semi-U dozer blade with push beams, cupped end bits, and tilt cylinder	*U blade with push beams, cupped end bits, and tilt cylinder*
	Weight		
	With Mechanical Pitch Adjustment	13,318 lb. (6041 kg)	14,908 lb. (6762 kg)
	With Power Pitch	13,567 lb. (6154 kg)	15,157 lb. (6875 kg)
	With Standard Cutting Edges without Spill Guard	7,033 lb. (3190 kg)	8,622 lb. (3911 kg)
	SAE Capacity	11.6 cu. yd. (8.92 m^3)	15.3 cu. yd. (11.7 m^3)
G	Height	5 ft. 5 in. (1.7 m)	5 ft. 5 in. (1.7 m)
H	Width	13 ft. 3 in. (4.04 m)	14 ft. 2 in. (4.3 m)
I	Lifting Height	4 ft. 7 in. (1.4 m)	4 ft. 7 in. (1.4 m)
J	Blade Digging Depth	22 in. (570 mm)	22 in. (570 mm)
K	Maximum Blade Pitch Adjustment	10 deg.	10 deg.
L	Maximum Tilt	3 ft. 2 in. (972 mm)	3 ft. 5 in. (1043 mm)
M	Overall Length	21 ft. 4 in. (6.5 m)	22 ft. 8 in. (6.9 m)

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1.7.2.1 Large Dozer with a Single-Shank and Multishank Rear Ripper Blade

The 1050J.



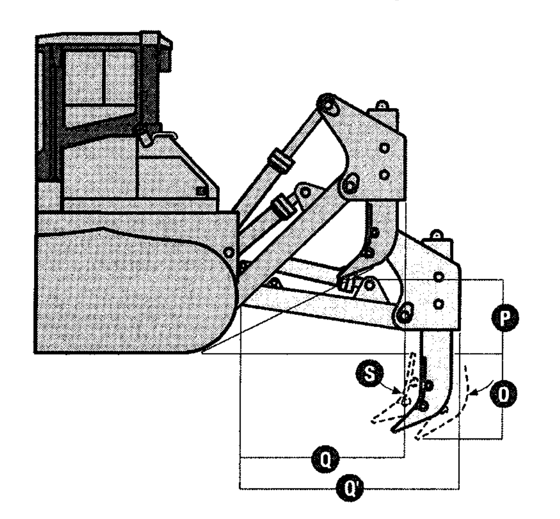


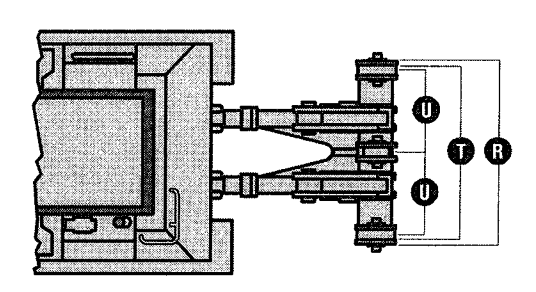
1050J DOZER WITH SINGLE-SHANK REAR RIPPER

Rear Ripper

Parallelogram ripper with hydraulic pitch adjustment

		single-shank (3-hole height adjustment in each shank)	*multi-shank (3) with hydraulic pitch (2-hole height adjustment in each shank)*
	Weight	7,974 lb. (3617 kg)	10,509 lb. (4767 kg)
N	Ripping Depth		
	Maximum	3 ft. 11 in. (1201 mm)	2 ft. 7 in. (791 mm)
	Minimum	17 in. (421 mm)	19 in. (476 mm)
O	Lifting Height		
	Maximum	3 ft. 5 in. (1040 mm)	3 ft. 3 in. (985 mm)
	Minimum	10 in. (260 mm)	19 in. (476 mm)
P	Overall Length (attachment raised)	6 ft. 0 in. (1.8 m)	6 ft. 0 in. (1.8 m)
P'	Overall Length (attachment lowered)	7 ft. 9 in. (2.4 m)	7 ft. 9 in. (2.4 m)
Q	Toolbar Width	4 ft. 4 in. (1.3 m)	8 ft. 0 in. (2.4 m)
R	Distance Between Teeth		3 ft. 7 in. (1.1 m)
S	Maximum Pitch Adjustment	31 deg.	31 deg.





1050J DOZER WITH MULTI-SHANK REAR RIPPER

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1.8.0 Skid Loader

In 1957 a pair of local blacksmiths, the Keller brothers, produced a three-wheeled loader, built on a farm from junkyard parts, that evolved into today's popular Bobcat. This machine designed for small-space work and operated by locking one track or wheel to turn quickly in close quarters became the popular skid steer loader offered by many equipment manufacturers today.

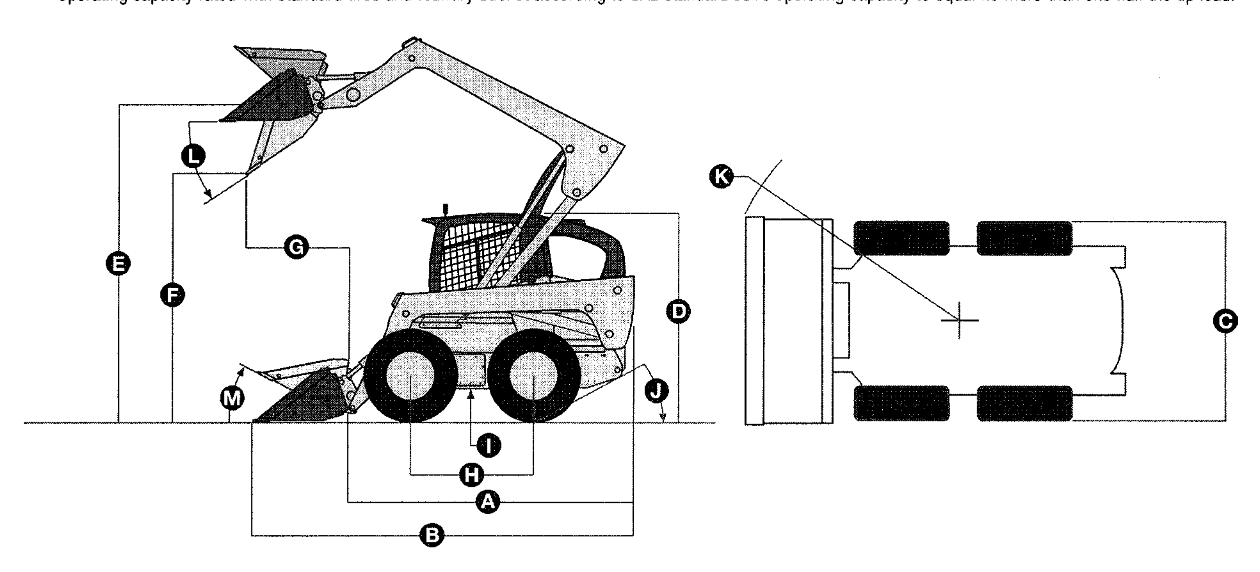
1.8.1 Small Skid Steer Loader

Deere loader with tipping load of 3700 lb (1678 kg).

Loader Performance

Tipping Load ....3,700 lb. (1678 kg)
SAE Rated Operating Capacity[1] ....1,750 lb. (794 kg)
ROC with Optional Counterweights....2,100 lb. (953 kg)
Boom Breakout ....3,100 lb. (1406 kg)
Bucket Breakout:
  Foundry Bucket ....5,500 lb. (2495 kg)
  Construction Bucket ....3,900 lb. (1769 kg)

[1]Operating capacity rated with standard tires and foundry bucket according to SAE standard J818 operating capacity to equal no more than one half the tip load.



Dimensions

A Length without Bucket ....102 in. (2591 mm)
B Length with Bucket ....125.8 in. (3195 mm)
C Width without Bucket ....64.1 in. (1628 mm)
D Height to Top of ROPS ....75.4 in. (1915 mm)
E Height to Hinge Pin ....114 in. (2896 mm)
F Dump Height ....88.8 in. (2255 mm)
G Dump Reach:
  Foundry Bucket ....29.1 in. (739 mm)
  Construction Bucket ....36 in. (914 mm)
H Wheelbase ....42.3 in. (1074 mm)
I Ground Clearance ....8.2 in. (208 mm)
J Angle of Departure ....27 degrees
K Front Turn Radius ....78.9 in. (2004 mm)
L Dump Angle (At Full Lift Height) ....45 degrees
M Bucket Rollback (At Ground Level) ....35 degrees

Operating Weight

Operating Weight ....6,300 lb. (2858 kg)

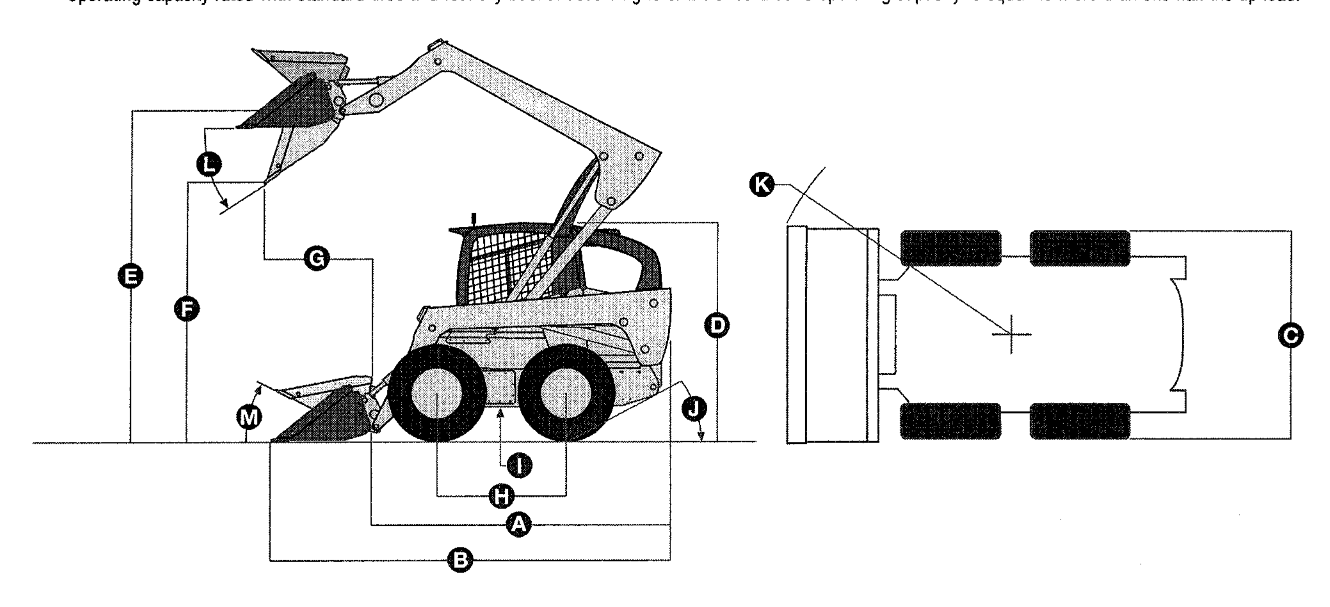
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1.8.2 Skid Steer Loader with Tipping Load of 3900 lb (1769 kg)

Loader Performance

Tipping Load ....3,900 lb. (1769 kg)
SAE Rated Operating Capacity[1] ....1,950 lb. (885 kg)
ROC with Optional Counterweights................2,300 lb. (1043 kg)
Boom Breakout ....3,100 lb. (1406 kg)
Bucket Breakout:
Foundry Bucket ....5,500 lb. (2495 kg)
Construction Bucket ....3,900 lb. (1769 kg)

[1]Operating capacity rated with standard tires and foundry bucket according to SAE standard J818 operating capacity to equal no more than one half the tip load.



Dimensions

A Length without Bucket ....102 in. (2591 mm)
B Length with Bucket ....125.8 in. (3195 mm)
C Width without Bucket.............................69.8 in. (1773 mm)
D Height to Top of ROPS...........................76.8 in. (1951 mm)
E Height to Hinge Pin ....115.2 in. (2926 mm)
F Dump Height..90.2 in. (2290 mm)
G Dump Reach:
Foundry Bucket ....28.1 in. (714 mm)
Construction Bucket ....35 in. (889 mm)
H Wheelbase ....42.3 in. (1074 mm)
I Ground Clearance ....9.6 in. (244 mm)
J Angle of Departure.................................27 degrees
K Front Turn Radius..................................78.9 in. (2004 mm)
L Dump Angle (At Full Lift Height) ....45 degrees
M Bucket Rollback (At Ground Level) ....35 degrees

Operating Weight

Operating Weight ....6,435 lb. (2919 kg)

By permission, Deere & Company, Moline, Illinois.

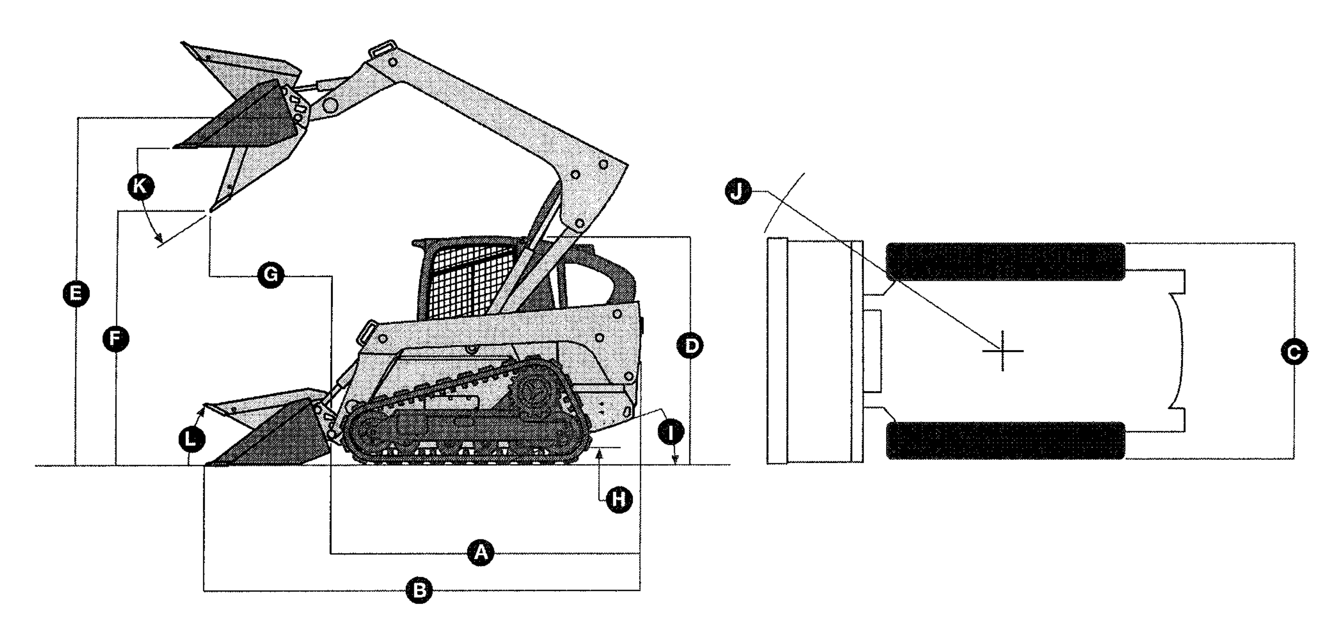
1.8.3 Compact Track Loader

Deere model CT322, with tipping load of 9200 lb (4173 kg).

Loader Performance

Tipping Load .... 9,200 lb. (4173 kg)
SAE Rated Operating Capacity @ 35%
of Tipping Load' .... 3,200 lb. (1452 kg)
SAE Rated Operating Capacity @ 50%
of Tipping Load.................... 4,600 lb. (2087 kg)
Boom Breakout .... 6,650 lb. (3016 kg)
Bucket Breakout:
Heavy-Duty Foundry Bucket .... 11,600 lb. (5262 kg)
Heavy-Duty Construction Bucket...... 8,210 lb. (3724 kg)
Tractive Effort....................... 11,500 lbf (5227 kgf)

'Operating capacity rated with 17.7-in. (450 mm) tracks and foundry bucket according to SAE standard J818 operating capacity to equal no more than 35% of the tip load.



Dimensions

A Length without Bucket............. 115.5 in. (2934 mm)
B Length with Bucket............... 138.5 in. (3518 mm)
C Width without Bucket .... 80.6 in. (2047 mm)
D Height to Top of ROPS............. 82.9 in. (2106 mm)
E Height to Hinge Pin .... 127 in. (3226 mm)
F Dump Height.................... 102 in. (2591 mm)
G Dump Reach:
Heavy-Duty Foundry Bucket ...... 33 in. (841 mm)
Heavy-Duty Construction Bucket..... 40 in. (1019 mm)
H Ground Clearance .... 11 in. (279 mm)
I Angle of Departure .... 27.6 degrees
J Front Turn Radius .... 83.7 in. (2126 mm)
K Dump Angle (at full lift height)....... 45 degrees
L Bucket Rollback (at ground level) .... 35 degrees

Operating Weight

Standard 17.7-in. (450 mm) Track .... 10,825 lb. (4910 kg)
Optional 12.6-in. (320 mm) Track........ 10,565 lb. (4792 kg)

By permission, Deere & Company, Moline, Illinois.

1.8.3.1 Weight of Loose Material, Pounds per Cubic Yard and Metric Equivalent

MATERIAL (Loose weight)	lb./cu. yd.	kg/m^3
Caliche	2,100	1250
Cinders	1,000	590
Clay and gravel, dry	2,400	1420
Clay and gravel, wet	2,600	1540
Clay, dry	2,500	1480
Clay, natural bed	2,800	1660
Clay, wet	2,800	1660
Coal, anthracite, broken	1,850	1100
Coal, bituminous, broken	1,400	830
Earth, dry, packed	2,550	1510
Earth, loam	2,100	1250
Earth, wet, excavated	2,700	1600
Granite, broken or large crushed	2,800	1660
Gravel, dry	2,550	1510
Gravel, dry 1/2" to 2" (13 to 50 mm)	2,850	1690
Gravel, pit run (graveled sand)	3,250	1930
Gravel, wet 1/2" to 2" (13 to 50 mm)	3,400	2020
Gypsum, crushed	2,700	1600
Limestone, broken or crushed	2,600	1540
Magnetite, iron ore	4,700	2790
Phosphate rock	2,160	1280
Pyrite, iron ore	4,350	2580
Sand and gravel, dry	2,900	1720
Sand and gravel, wet	3,400	2020
Sand, dry	2,400	1420
Sand, wet	3,100	1840
Sandstone, broken	2,550	1510
Shale	2,100	1250
Slag, broken	2,950	1750
Stone, crushed	2,700	1600
Topsoil	1,600	950

1.9.0 Technology and Construction Equipment

Global positioning systems are employed by civil engineers and their survey parties. For several years, companies have offered estimating software that allows an estimator not only to make accurate sitework estimates but also to visually create 3D presentations of existing and new site contours to augment their estimate.

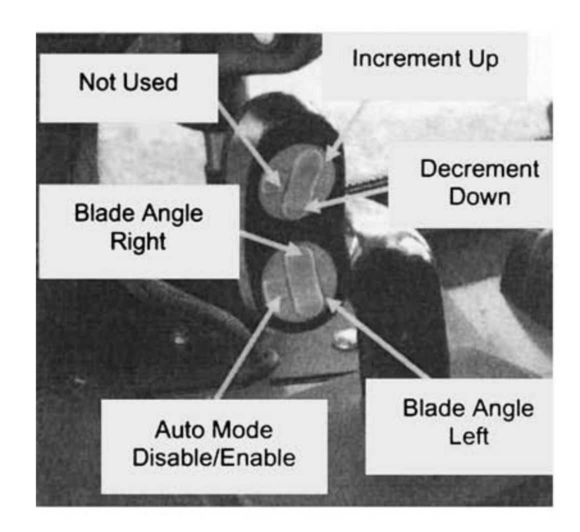
Now construction equipment manufacturers are beginning to use GPS and other computer software programs to aid equipment operators in attaining better control over their contour grading operations.

1.9.1 Caterpillar's Accugrade Grade Control System

Utilizing a laser transmitter and receiver and a GPS base station radio combined with digital operator design guidance features and automatic blade controls, a more accurate final rough grade can be obtained more quickly. Caterpillar's system utilizes the Accugrade laser. Their GPS base station radio and satellite technology compares the traditional grading method using grade stakes with their laser-guided system.

1.9.2 John Deere's Install Integrated Grade Control System

It utilizes a Trimble interface equipped with the Trimble GCS900 Grade Control System incorporating a GPS antenna and a laser augmentation configuration. The dozer operator uses the position and elevation information fed into an onboard computer and compares these data to the design cut and fill profile. This cut and fill information will drive the valves on the dozer for automatic blade control.



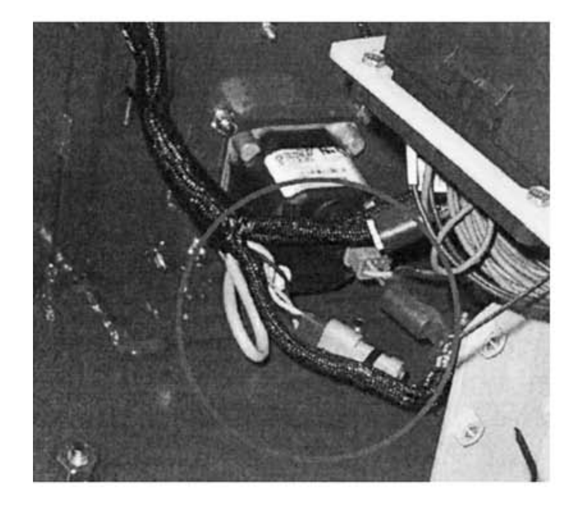
There are three functions added to the new IGC electro-hydraulic dozer control joystick.

- Auto Mode Disable/Enable
- Increment Up
- Decrement Down

These buttons will not be on the standard dozer joystick.

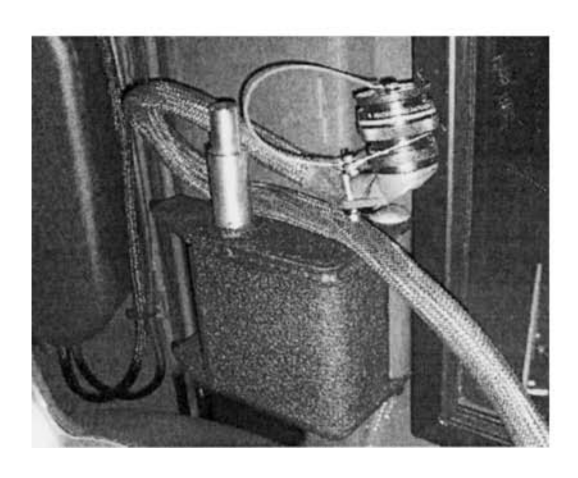
The Auto Mode Disable Switch allows the operator to select between manual and automatic modes without moving his hand from the dozer joystick control.

The optional fourth function for rear equipment is operated by a separate lever located to the right of the main control stick



As you can see, the mechanical linkage associated with the old joystick is eliminated with this new electro-hydraulic (EH) controller.

The control lever now works the same as the large dozer pilot controller to raise, lower, tilt, and angle the blade.



The Trimble monitor mount is located at the front of the right side console. The wire harness connects to the already existing Deere integrated connectors inside the console.

1.10.0 Trenchless Pipe Installation

Microtunneling, underground pipe jacking, and augur pipe jacking are practical methods to install and repair underground utilities in urban areas where open trench cut and cover are impractical.

1.10.1 Basic Types of Trenchless Technology

include microtunneling, horizontal directional drilling (HDD), and tunnel boring machines (TBMs).

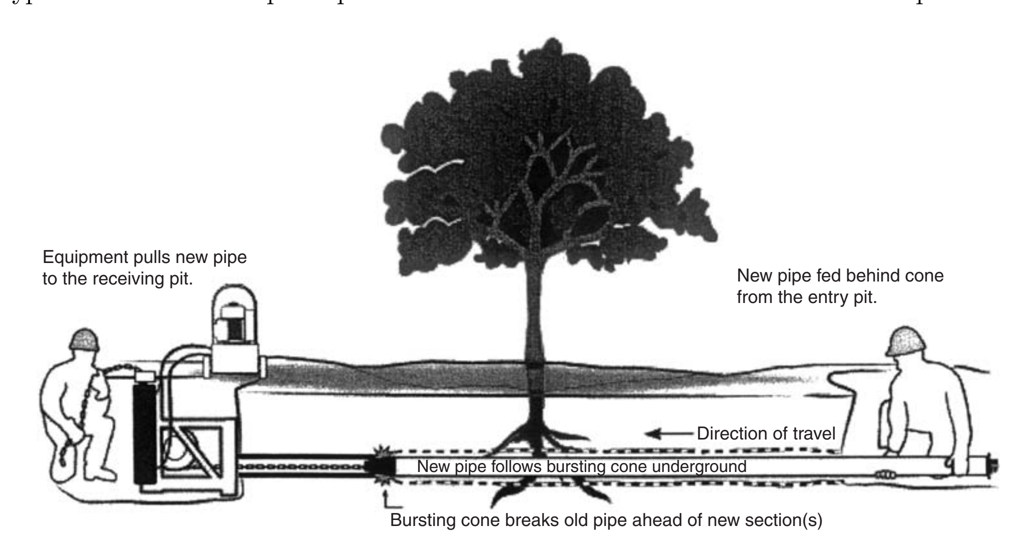
1.10.2 Microtunneling

A system to create a small-diameter tunnel to install a product pipe underground. This is a process whereby a remotely operated small boring machine, referred to as a *microtunnel boring machine* (MTBM), bores and brings along product pipelines as it bores a passage. This process is often referred to as *pipe jacking* since the tunnel liner is hydraulically pushed behind the boring that takes place. Overcutting of the bore provides a slight gap between the inside diameter of the bore and the outside diameter of the pipe. A bentonite slurry, an ecologically friendly lubricant, is injected into this gap to ease the passage of the pipe, but the process still involves some high hydraulic pressure to achieve passage.

The type of MTBM equipment is based upon the subsurface conditions likely to be encountered and includes a hydraulic jacking device, a lubricating system to ease the pipe installation, a closed-loop slurry system to remove the spoils, and a guidance system to control the path of the bore.

1.10.2.1 Typical Microtunneling Machine

Typical MTBM and the pit required to lower the TBM to the elevation of the required bore.



**Please note that for the purposes of this brief description, "pipe" refers to the line being pulled no matter what type.*

Trenchless Information Resources

For more information about trenchless pipe replacement we provide the following links.

Louisiana Tech University Trenchless Technology Center
The Trenchless Technology Center at the Louisiana Tech University is a university/industry cooperative research center advancing trenchless technology by serving as an independent source of knowledge, research and education.

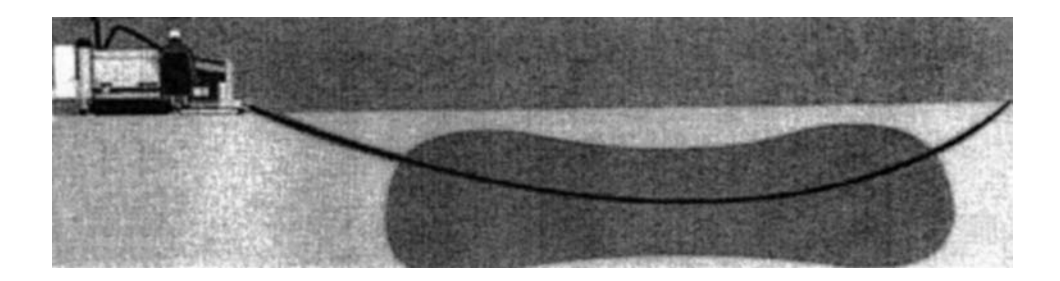
North American Society for Trenchless Technology (NASTT)
NASTT is the only organization in North America specifically and exclusively dedicated to the science and practice of Trenchless Technology.

International Society For Trenchless Technology (ISTT)
The International Society for Trenchless Technology provides information about and promotes trenchless pipeline installation and rehabilitation.

Source: Alpha Plumbing, Dallas, Texas.

1.10.2.2 Horizontal Directional Drilling (HDD) Method

This HDD process involves making a pilot bore into the ground at a slight angle, leveling out at a specified depth, and then advancing the boring machine horizontally along that depth to a point where the drill is directed to exit the ground. At that point the drill head is removed, and a back reamer or expander is attached along with the conduit or pipe that is to be installed. This pipe or conduit is then pulled back through the pilot hole.



1.10.3 Soil Displacement Method

A displacement hammer driven by a hydraulic pump or pneumatic pressure actually pushes a ram that creates a cavity which can be used to pull pipes through.

1.10.4 Trenchless Pipe Replacement

This involves installing a new pipe by pulling it through the existing one. By digging a pit on both ends of the pipe to be replaced, a pulling unit with a cone-shaped device acts as a breaking head to clear any collapsed pipe before the new insert is pulled through.

1.10.5 Tunnel Boring Machines (TBMs)

Boring machines are lowered into a pit at the elevation of either a proposed utility or a traffic tunnel. Depending upon the nature of the soil—cohesive, noncohesive, high water content, brittle, soft or hard rock—a variety of types of TBMs are employed to bore through the substrata under an active highway or rail line. Traffic tunneling TBMs range in diameter from 13 ft (4 m) to 49 ft (15 m); utility tunneling TBMs range in size from a 3-in (0.10-m) diameter to 14 ft (4.20 m).

1.11.0 Site Utilities

The installation of incoming underground utilities such as potable water, sanitary and storm sewers, natural gas and primary electrical service, and data communications services may involve various types of pipe and conduit, but they all have three things in common.

- Excavation and pipe installation via open cut or trench cut
- Bedding materials to ensure that the pipe or conduit will not be damaged upon backfill
- Compaction of the soil above the pipe to stabilize the excavate

The preparation of the trench to receive underground utilities starts with a proper foundation. A stable and uniform foundation is necessary for satisfactory performance of any pipe. The foundation must have sufficient load-bearing capacity to maintain the pipe in proper alignment and sustain the loads imposed. The foundation should be checked for hard or soft spots. When undesirable foundations exist, they should be stabilized by ballasting or soil modification.

1.11.1 Ballasting for Site Utilities

Ballasting requires the removal of undesirable foundation material and replacement with select material such as sand, gravel, crushed rock, slag, or suitable earth backfill. The depth, gradation, and size

of the ballast depend upon the specific material used and the amount of stabilization required. The ballast is usually well graded from coarse to fine, having a size not more than 1 in./ft of pipe diameter with 3 in. maximum and placed to a minimum depth of 4 in.

1.11.2 Soil Modification

involves the addition of select material to the native soil. Crushed rock, gravel, sand, slag, or other durable insert materials with a maximum size of 3 in. are worked into the subsoil to accomplish the required stabilization. Soil modification can also be accomplished by the addition of lime or cement.

1.11.3 Adequate Pipe Foundation Stability

This is difficult to evaluate by visual observation. However, when concrete pipe is set on the foundation with little or no care exercised to provide a bearing surface, the weight of the pipe exerts a pressure of approximately 1000 lb/ft^2 for large-diameter pipe. This pressure is about the same as a 200-lb person would exert when standing on one foot. If the foundation can support workers in a trench without sinking into the soil, the foundation should be stable enough to support the pipe and maintain it in proper alignment.

1.11.4 Foundation Preparation

A stable and uniform **foundation** is necessary for satisfactory performance of any pipe. The foundation must have sufficient load bearing capacity to maintain the pipe in proper alignment and sustain the loads imposed. The foundation should be checked for hard or soft spots. Where undesirable foundations exist, they should be stabilized by **ballasting** or **soil modification.**

Ballasting requires removal of undesirable foundation material and replacement with select materials such as sand, gravel, crushed rock, slag, or suitable earth backfill. The depth, gradation and size of the ballast depend on the specific material used and the amount of stabilization required. The ballast is usually well graded from coarse to fine, having a size not more than one inch per foot of pipe diameter with three inches maximum and placed to a minimum depth of four inches.

Soil modification involves the addition of select material to the native soil. Crushed rock, gravel, sand, slag or other durable inert materials with a maximum size of three inches are worked into the subsoil to accomplish the required stabilization. Soil modification can also be accomplished by the addition of lime, cement or chemicals to the soil.

Adequate foundation stability is difficult to evaluate by visual observation. However, when concrete pipe is set on the foundation with little or no care exercised to provide a bearing surface, the weight of the pipe exerts a pressure of approximately 1000 pounds per square foot. This pressure is about the same pressure a 200 pound man would exert when standing on one foot. If the foundation can support men working in the trench without sinking into the soil, the foundation should be stable enough to support the pipe and maintain it in proper alignment.

1.11.5 Pipe Bedding

Once a stable and uniform foundation is provided, it is necessary to prepare the **bedding** in accordance with the requirements of the plans, specifications or standard drawings. An important function of the bedding is to assure uniform support along the barrel of each pipe section. The bedding distributes the load reaction around the lower periphery of the pipe. The required supporting strength of the pipe is directly related to this load distribution, and several types of bedding have been established to enable specification of pipe strengths during the design phase of the project.

Pipe set on a flat foundation without bedding results in high load concentration at the bottom of the pipe. Bedding the pipe so that the bottom reaction is distributed over 50 percent of the outside horizontal span of the pipe results in a 36 percent increase in supporting strength; a 60 percent distribution results in a 73 percent increase for the same amount of settlement; and a 100 percent distribution results in as much as a 150 percent increase depending on sidefill compaction.

If the pipe strength specified for a particular project is based on a design assumption that at least 60 percent of the outside horizontal span of the pipe is bedded, and the pipe is actually set on a flat foundation, a pipe strength significantly greater than specified would be required. The bedding being constructed needs to be continuously compared with the requirements in the plans or specifications.

Improved construction practices enable variations in the methods used to attain the required bearing surface at the bottom of the pipe. The general classifications of beddings are presented as a guideline of what is reasonably obtainable. Based on current construction practices, it is generally more practical and economical to over excavate and bed the pipe on select materials, rather than shape the subgrade to conform to the shape of the pipe.

1.11.6 Class D, C, B, and A Bedding

CLASS D BEDDING

Class D bedding is used only with circular pipe. Little or no care is exercised either to shape the foundation surface to fit the lower part of the pipe exterior or to fill all spaces under and around the pipe with granular materials. However, the gradient of the bed should be smooth and true to the established grade. This class of bedding also includes the case of pipe on rock foundations in which an earth cushion is provided under the pipe but is so shallow that the pipe, as it settles under the influence of vertical load, approaches contact with the rock.

CLASS C BEDDING

With a **shaped subgrade** the pipe is bedded with ordinary care in a soil foundation, shaped to fit the lower part of the pipe exterior with reasonable closeness for a width of at least 50 percent of the outside diameter for a circular pipe, and one-tenth of the outside pipe rise for arch pipe, elliptical pipe and box sections. For trench installations the sides and area over the pipe are filled with lightly compacted backfill to a minimum depth of six inches above the top of the pipe. For embankment installations the pipe should not project more than 90 percent of the vertical height of the pipe above the bedding.

A **granular foundation** is used only with a circular pipe, and consists of a compacted granular material or densely compacted backfill placed on a flat bottom trench. The bedding material should extend up the sides for a height of at least one-sixth the outside diameter of the pipe.

CLASS B BEDDING

For a **shaped subgrade** with granular foundation the bottom of the excavation is shaped to conform to the pipe surface but at least two inches greater than the outside dimensions of the pipe. The width should be sufficient to allow six-tenths of the outside pipe diameter for circular pipe and seven-tenths of the outside span for arch and elliptical pipe to be bedded in fine granular fill placed in the shaped excavation. Densely compacted backfill should be placed at the sides of the pipe to a depth of at least 12 inches above the top of the pipe.

A **granular foundation** without shaping is used only with circular pipe. The pipe is bedded in compacted granular material placed on the flat trench bottom. The granular bedding has a minimum thickness, and should extend at least halfway up the pipe at the sides. The remainder of the side fills, and a minimum depth of 12 inches over the top of the pipe, should be filled with densely compacted material.

CLASS A BEDDING

A **concrete craddle** bedding is used only with circular pipe. The pipe is bedded in nonreinforced or reinforced concrete having thickness, *d,* and extending up the sides for a height equal to one-fourth the outside diameter. The cradle should have a minimum width at least equal to the outside diameter of the pipe plus eight inches. The backfill above the cradle is densely compacted and extends 12 inches above the crown of the pipe. In rock, especially where blasting is likely in the adjacent vicinity, the concrete cradle should be cushioned from the shock of the blasting which can be transmitted through the rock.

The **concrete arch** is an alternate to the concrete cradle for trench installations. The pipe is bedded in carefully compacted granular material having the minimum thickness and extending halfway up the sides of the pipe. The top half of the pipe is covered with nonreinforced or reinforced

concrete having a minimum thickness over the top of the pipe of one-fourth the inside pipe diameter. The arch should have a minimum width at least equal to the outside diameter of the pipe plus eight inches.

BEDDING MATERIALS

Materials for bedding should be selected to intimate contact can be obtained between the bed and the pipe. Since most granular materials will shift to attain this contact as the pipe settles, an ideal load distribution can be realized. Granular materials are coarse sand, pea gravel or well graded crushed rock.

With the development of mechanical methods for subgrade preparation, pipe installation, backfilling and compaction, excellent results have been obtained with pipe installed on a flat bottom foundation and backfilled with well graded, job excavated soil. If this method of bedding is used, it is essential that the bedding material be uniformly compacted under the haunches of the pipe.

Where ledge rock, compacted rocky or gravel soil, or other unyielding foundation material is encountered, beddings should be modified as follows:

- For Class B and C beddings, subgrades should be excavated or overexcavated, if necessary, so a uniform foundation free of protruding rocks is provided.
- Special care may be necessary with Class A beddings or other unyielding foundations to cushion pipe from shock when blasting can be anticipated in the area.

By permission, American Concrete Pipe Association, Irving, Texas.

1.11.7 Pipe Zone Bedding Materials

- *Class I* Angular stone, graded from ¼″ (6.4 mm) to ½″ (12.7 mm), including crushed stone, crushed shells, and cinders.
- *Class II* Coarse sand with a maximum particle size of 1½″ (38.1 mm), including various graded sands and gravel containing small percentages of fines. Soil type GW, SP, SM, and C* (See the unified soil classification listing).
- *Class III* Fine sand and clayey gravel, including fine sand, sand-clay mixtures, and gravel-clay mixes. Soil types GM, GC, SM, and SC are included in this class.
- *Class IV* Silt, silty clays (including inorganic clays), and silts of medium to high plasticity and liquid limits. Soil types MH, ML, CH, and CL are included in this class.
- *Class V* Soils not recommended for bedding, haunching, or initial backfill consisting of organic silts, organic clays and peat, and other highly organic materials.

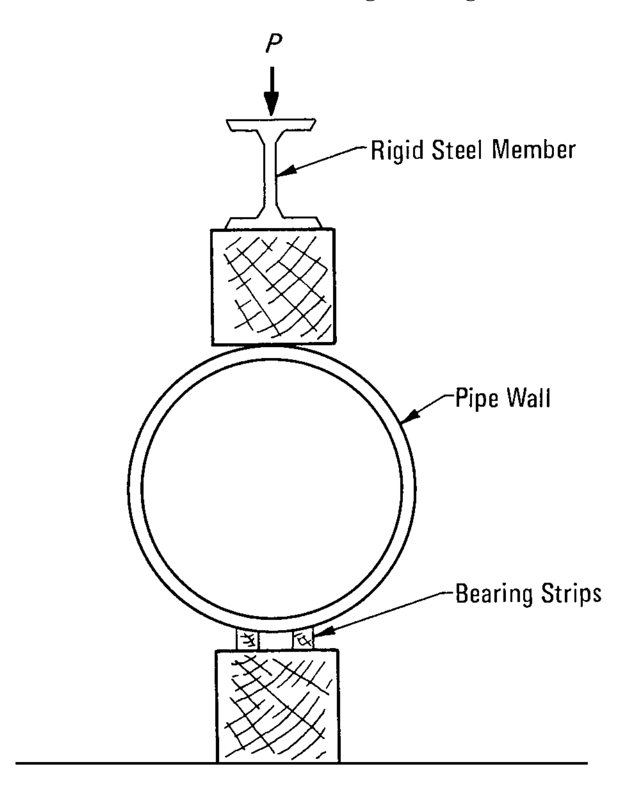
Common sense, experience, and OSHA regulations will dictate the precautions required during site utilities excavation. OSHA Handbook *Title 29 of the Code of Federal Regulations* (29 CFR Part 1926) is to be referred to for detailed regulations regarding excavation and trenching operations. OSHA *Construction Industry Digest* (OSHA 2202) is a pocket-sized digest of basic applicable standards, including excavation and trenching. This handy booklet can be obtained by calling the local U.S. Department of Labor office.

1.11.8 Loads on Pipe

Three types of loads must be considered:

1. **Earth loads**
2. **Live loads** from trucks, aircraft, and trains
3. **Surcharge loads** or loads from an additional earth fill or building over an installed pipe

The methods for determining the magnitude of these loads are discussed in the following section.



Three-Edge Bearing Test

1.11.9 Backfilling Procedures for Thermoplastic Pipe

Backfilling

Before making the final connections and backfilling, the pipeline should be cooled to near the temperature of the soil. During hot weather, for example, backfilling should be done early in the morning, when the solvent-cemented joints are completely dried and the line is fully contracted.

Assuming that the pipe is uniformly and continuously supported over its entire length on firm, stable material, it should first be covered with 6 to 8 in. of soil that is free of debris and rocks larger than on-half inch in diameter. This initial layer should be compacted by hand or, preferably, by mechanical tamper so that it acts as a protective cushion against the final backfill. Any large, sharp rock that could penetrate the tampered layer around the pipe should be removed from the final backfill.

Heavy Traffic: When plastic pipe is installed beneath streets, railroads or other surfaces that are subjected to heavy traffic and resulting shock and vibration, it should be run within a protective metal or concrete casing.

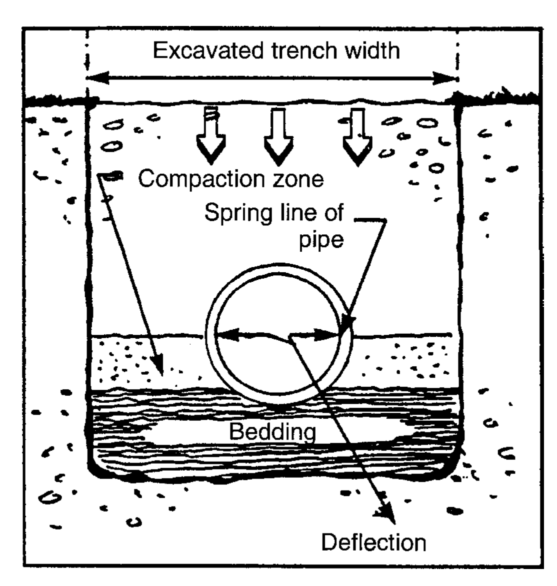
Locating Buried Pipe: The location of plastic pipelines should be accurately recorded at the time of installation. Since pipe is a non-conductor, it does not respond to the electronic devices normally used to locate metal pipelines. However, a copper or galvanized wire can be spiraled around, taped to or laid alongside or just above the pipe during installation to permit the use of a locating device.

Note: For additional information, see ASTM D 2774, "Underground Installation of Thermoplastic Piping."

1.11.10 Compaction of Backfill for Metal and Thermoplastic Sewer Pipe

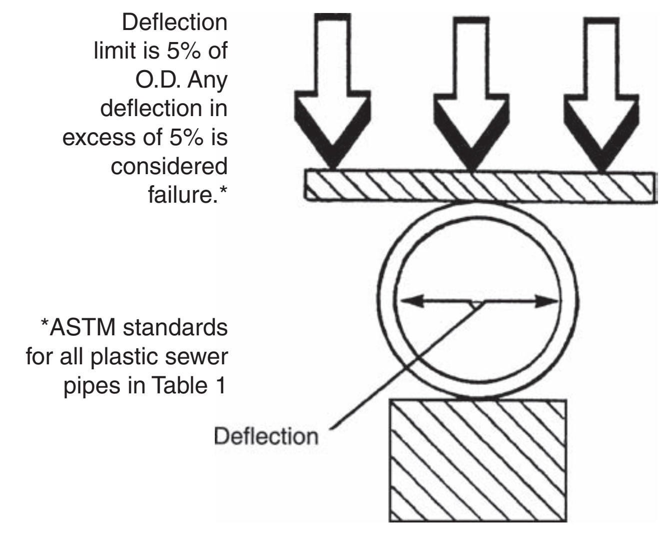
The pipe, once installed and inspected, must be backfilled.

- **Cast iron soil pipe—Special compaction of the backfill is not necessary** except for meeting the requirements of normal compaction of the excavated area. Because cast iron is **"rigid,"** it does not depend on sidefill support.
- **Thermoplastic sewer pipe**—The **"flexible"** pipe design is dependent on sidefill support to gain **"stiffness"** to control deflections within acceptable limits (see figure below). **Compaction in six-inch maximum layers is required** to the springline of the pipe. Compaction around the pipe must be by hand. As noted earlier, trench width must be sufficient to allow this compaction. Depending on soil type, minimum density compaction can range from 85 to 95 percent. If the installation does not have suitable backfill material available, it must be imported.



Special bedding requirements per ASTM D2321-89

1.11.11 Deflection of Cast Iron and Thermoplastic Sewer Pipe



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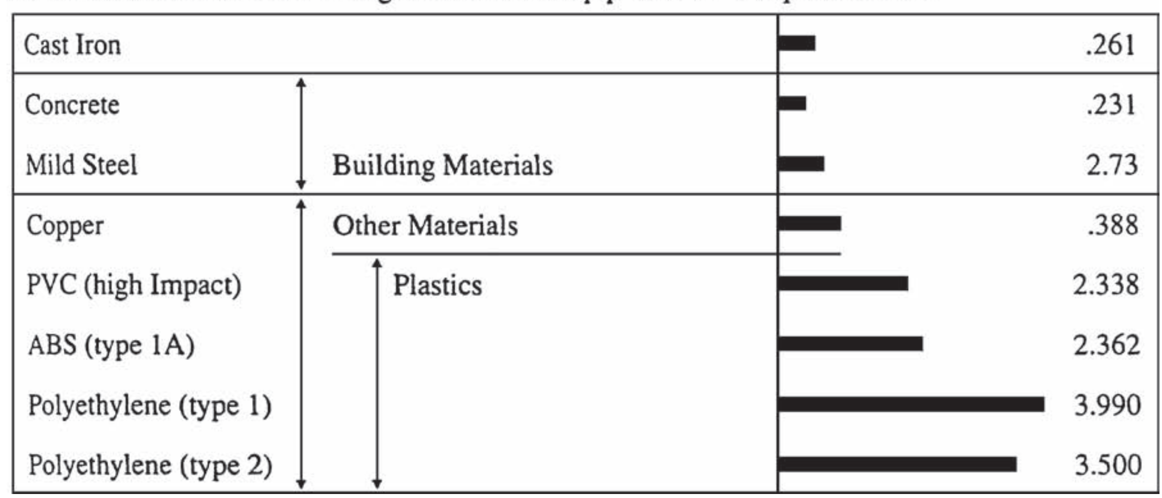
1.11.12 Expansion Characteristics of Various Metal and Plastic Pipes

Expansion: Allowances for expansion and contraction of building materials are important design considerations. Material selection can create or prevent problems. Cast iron is in tune with building reactions to temperature. Its expansion is so close to that of steel and masonry that there is no need for costly expansion joints and special offsets. That is not always the case with other DWV materials.

Thermal expansion of various materials.

Material	Inches per inch $10^{-6} \times$ per °F	Inches per 100′ of pipe per 100°F.	Ratio-assuming cast iron equals 1.00
Cast iron	6.2	0.745	1.00
Concrete	5.5	0.66	.89
Steel (mild)	6.5	0.780	1.05
Steel (stainless)	7.8	0.940	1.26
Copper	9.2	1.11	1.49
PVC (high impact)	55.6	6.68	8.95
ABS (type 1A)	56.2	6.75	9.05
Polyethylene (type 1)	94.5	11.4	15.30
Polyethylene (type 2)	83.3	10.0	13.40

Here is the *actual* increase in length for 50 feet of pipe and 70° temperature rise.



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1.11.12 Expansion Characteristics of Various Metal and Plastic Pipes (Continued)

CPVC Expansion Loops

CPVC		Length of Run (feet)									
		10	20	30	40	50	60	70	80	90	100
Pipe Size (in.)	O.D. of Pipe (in.)	Minimum Deflected Pipe Length (DPL) (inches)									
1/2	0.840	15	21	26	30	33	36	39	42	44	47
3/4	1.050	17	23	29	33	37	40	44	47	50	52
1	1.315	18	26	32	37	41	45	49	52	55	58
1 1/4	1.660	21	29	36	42	46	51	55	59	62	66
1 1/2	1.900	22	31	39	44	50	54	59	63	67	70
2	2.375	25	35	43	50	56	61	66	70	75	79
3	3.500	30	43	52	60	67	71	80	85	91	95
4	4.500	34	4	59	68	77	84	91	97	103	108
6	6.625	42	59	72	83	93	102	110	117	125	131
8	8.625	47	67	82	95	106	116	125	134	142	150
10	10.750	53	75	92	106	118	130	140	150	159	167
12	12.750	58	81	100	115	129	141	152	163	173	182

CPVC Offsets and Change of Directions

CPVC		Length of Run (feet)									
		10	20	30	40	50	60	70	80	90	100
Pipe Size (in.)	O.D. of Pipe (in.)	Minimum Deflected Pipe Length (DPL) (inches)									
1/2	0.840	21	30	36	42	47	51	55	59	63	66
3/4	1.050	23	33	40	47	22	57	62	66	70	74
1	1.315	26	37	45	52	58	61	69	74	78	83
1 1/4	1.660	29	42	51	59	66	72	78	86	88	93
1 1/2	1.900	31	44	54	63	70	77	83	89	94	99
2	2.375	35	50	61	70	79	86	93	99	105	111
3	3.500	43	60	74	85	95	105	113	121	128	135
4	4.500	48	68	84	97	108	119	128	137	145	153
6	6.625	59	53	102	117	131	144	155	166	176	186
8	8.625	67	95	116	134	150	164	177	189	201	212
10	10.750	75	106	130	150	167	183	198	212	224	237
12	12.750	81	115	141	163	182	200	216	230	244	258

Figure C: Expansion Offset

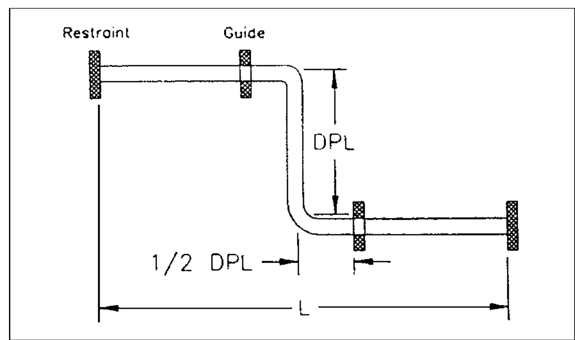
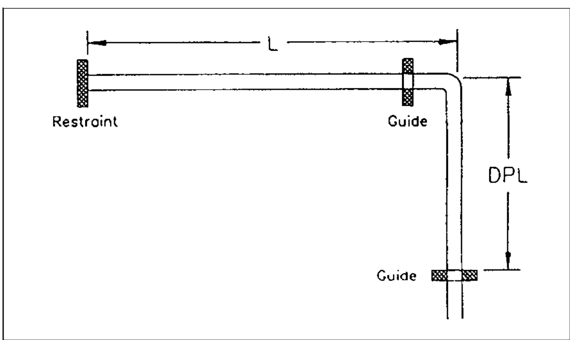
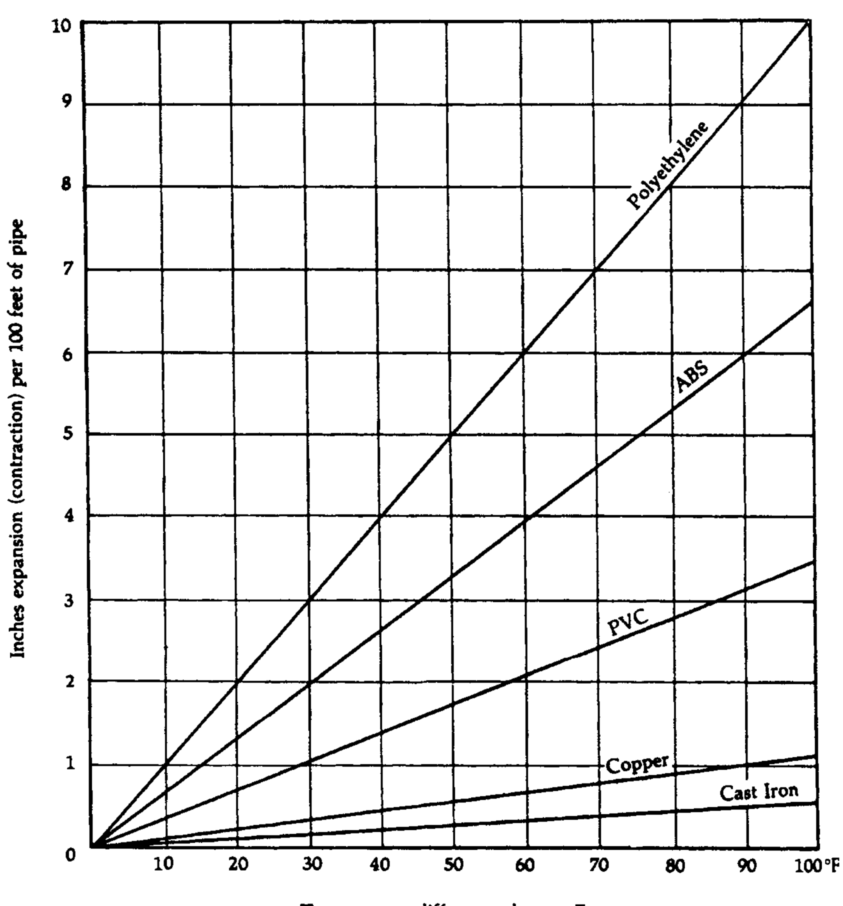


Figure D: Change of Direction



1.11.13 Expansion Characteristics of Metal and Plastic Pipe in Graph Form



Example: Find the expansion allowance required for a 120 ft. run of ABS pipe in a concrete & masonry building and for a temperature difference of 90°F.

Answer: At a temperature difference of 90°F read from the chart, ABS expands 6″ and concrete expands ¾″.

$(6 - \frac{3}{4}) \times \frac{120}{100} = 5\frac{1}{4} \times \frac{120}{100} = 6.3$ inches

1.11.14 Schedule 40, 80, and 120 PVC and CPVC Pipe Dimensions



Product Specifications

CPVC Industrial Pipe: Schedule 40 & 80

Schedule 40 Dimensions

Nom. Pipe Size (in.)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P
1/4	0.540	0.344	0.088	0.096	780
3/8	0.675	0.473	0.091	0.128	620
1/2	0.840	0.602	0.109	0.190	600
3/4	1.050	0.804	0.113	0.253	480
1	1.315	1.029	0.133	0.371	450
1-1/4	1.660	1.360	0.140	0.502	370
1-1/2	1.900	1.590	0.145	0.599	330
2	2.375	2.047	0.154	0.803	280
2-1/2	2.875	2.445	0.203	1.267	300
3	3.500	3.042	0.216	1.660	260
3-1/2	4.000	3.521	0.226	1.996	240
4	4.500	3.998	0.237	2.363	220
5	5.563	5.016	0.258	2.874	190
6	6.625	6.031	0.280	4.164	180
8	8.625	7.942	0.322	6.268	160
10	10.750	9.976	0.365	8.886	140
12	12.750	11.889	0.406	11.751	130
14	14.000	13.073	0.437	13.916	130
16	16.000	14.940	0.500	18.167	130
18	18.000	16.809	0.562	22.965	130
20	20.000	18.743	0.593	29.976	120
24	24.000	22.544	0.687	37.539	120

Schedule 80 Dimensions

Nom. Pipe Size (in.)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P.
1/4	0.540	0.282	0.119	0.117	1130
3/8	0.675	0.403	0.126	0.162	920
1/2	0.840	0.526	0.147	0.238	850
3/4	1.050	0.722	0.154	0.322	690
1	1.315	0.936	0.179	0.473	630
1-1/4	1.660	1.255	0.191	0.654	520
1-1/2	1.900	1.476	0.200	0.793	470
2	2.375	1.913	0.218	1.097	400
2-1/2	2.875	2.290	0.276	1.674	420
3	3.500	2.864	0.300	2.242	370
3-1/2	4.000	3.326	0.318	2.735	350
4	4.500	3.786	0.337	3.277	320
5	5.563	4.768	0.375	4.078	290
6	6.625	5.709	0.432	6.258	280
8	8.625	7.565	0.500	9.506	250
10	10.750	9.493	0.593	14.095	230
12	12.750	11.294	0.687	19.392	230
14	14.000	12.410	0.750	23.261	220
16	16.000	14.213	0.843	29.891	220
18	18.000	16.014	0.937	37.419	220
20	20.000	17.814	1.031	45.789	220
24	24.000	21.418	1.218	64.959	210

ASTM STANDARD D1784 MATERIAL EQUIVALENTS:
Cell Classification 23447 = CPVC Type IV Grade I = CPVC 4120

PIPE SIZES SHOWN ARE MANUFACTURED IN STRICT COMPLIANCE WITH ASTM F441

The pressure ratings given are for water, non-shock, @ 73°F. The following temperature de-rating factors are to be applied to the working pressure ratings listed when operating at elevated temperatures.

Multiply the working pressure rating of the selected pipe at 73°F, by the appropriate de-rating factor to determine the maximum working pressure rating of the pipe at the elevated temperature chosen.

EX: 10" CPVC SCH 80
@ 120°F = ?
230 psi x 0.65 =
149.5 psi max. @ 120°F

De-Rating Factor

Operating Temp (°F)	De-Rating Factor
73-80	1.00
90	0.91
100	0.82
110	0.72
120	0.65
130	0.57
140	0.50
150	0.42
160	0.40
170	0.29
180	0.25
200	0.20

THE MAXIMUM SERVICE TEMPERATURE FOR CPVC IS 200°F.

Solvent-cemented joints should be utilized when working at or near maximum temperatures. Harvel Plastics does not recommend the use of CPVC for threaded connections at temperatures above 150°F; use flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures.

Threading of Sch 40 CPVC pipe is not a recommended practice due to insufficient wall thickness. Thread only Sch 80 or heavier walls. **Threading requires a 50% reduction in pressure rating stated for plain end pipe @73°F.**

Chemical resistance data should be referenced for proper material selection and possible de-rating when working with fluids other than water. Refer to Harvel Plastics 112/401 Product Bulletin for chemical resistance and installation data.

By permission, Harvel Plastics, Easton, PA.

1.11.14 Schedule 40, 80, and 120 PVC and CPVC Pipe Dimensions (Continued)



Product Specifications

PVC Industrial Pipe: Schedule 80

Schedule 80 Dimensions

Nom. Pipe Size (in.)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P.
1/8	0.405	0.195	0.095	0.063	1230
1/4	0.540	0.282	0.119	0.105	1130
3/8	0.675	0.403	0.126	0.146	920
1/2	0.840	0.526	0.147	0.213	850
3/4	1.050	0.722	0.154	0.289	690
1	1.315	0.936	0.179	0.424	630
1-1/4	1.660	1.255	0.191	0.586	520
1-1/2	1.900	1.476	0.200	0.711	470
2	2.375	1.913	0.218	0.984	400
2-1/2	2.875	2.290	0.276	1.500	420
3	3.500	2.864	0.300	2.010	370
3-1/2	4.000	3.326	0.318	2.452	350
4	4.500	3.786	0.337	2.938	320
5	5.563	4.768	0.375	4.078	290
6	6.625	5.709	0.432	5.610	280
8	8.625	7.565	0.500	8.522	250
10	10.750	9.493	0.593	12.635	230
12	12.750	11.294	0.687	17.384	230
14	14.000	12.410	0.750	20.852	220
16	16.000	14.213	0.843	26.810	220
18	18.000	16.014	0.937	33.544	220
20	20.000	17.814	1.031	41.047	220
24	24.000	21.418	1.218	58.233	210

The pressure ratings given are for water, non-shock, @ 73°F. The following temperature de-rating factors are to be applied to the working pressure ratings (WP) listed when operating at elevated temperatures.

Multiply the working pressure rating of the selected pipe at 73°F, by the appropriate de-rating factor to determine the maximum working pressure rating of the pipe at the elevated temperature chosen.

De-Rating Factor

Operating Temp (°F)	De-Rating Factor
73	1.00
80	0.88
90	0.75
100	0.62
110	0.51
120	0.40
130	0.31
140	0.22

EX:
10" PVC SCH 80 @ 120°F = ?
230 psi x 0.40 = 92 psi max.
@ 120°F

THE MAXIMUM SERVICE TEMPERATURE FOR PVC IS 140°F.

Solvent-cemented joints should be utilized when working at or near maximum temperatures. Harvel Plastics does not recommend the use of PVC for threaded connections at temperatures above 110°F; use flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures.

Thread only Schedule 80 or heavier walls. ***Threading requires a 50% reduction in pressure rating stated for plain end pipe @73°F.*** Threading of Schedule 40 PVC pipe is not a recommended practice due to insufficient wall thickness.

Chemical resistance data should be referenced for proper material selection and possible de-rating when working with fluids other than water. Refer to Harvel Plastics 112/401 Product Bulletin for chemical resistance, installation data, and additional information.

ASTM STANDARD D1784 MATERIAL EQUIVALENTS:

Cell Classification 12454 = PVC Type I Grade I = PVC1120

Pipe sizes shown are manufactured in strict compliance with ASTM D1785.

By permission, Harvel Plastics, Easton, PA.

1.11.14 Schedule 40, 80, and 120 PVC and CPVC Pipe Dimensions (Continued)



Product Specifications

PVC Industrial Pipe: Schedule 120

Schedule 120 Dimensions

Nom. Pipe Size (in.)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P.
1/2	0.840	0.480	0.170	0.236	1010
3/4	1.050	0.690	0.170	0.311	770
1	1.315	0.891	0.200	0.464	720
1-1/4	1.660	1.204	0.215	0.649	600
1-1/2	1.900	1.423	0.225	0.787	540
2	2.375	1.845	0.250	1.111	470
2-1/2	2.875	2.239	0.300	1.615	470
3	3.500	2.758	0.350	2.306	440
4	4.500	3.574	0.437	3.713	430
6	6.625	5.434	0.562	7.132	370
8	8.625	7.189	0.718	11.277	380

ASTM STANDARD D1784 MATERIAL EQUIVALENTS:
Cell Classification 12454 = PVC Type I Grade I = PVC1120

PIPE SIZES SHOWN ARE MANUFACTURED IN STRICT COMPLIANCE WITH ASTM D1785

The working pressure ratings (W.P.) given are for water, non-shock, @ 73°F. The following temperature de-rating factors are to be applied to the working pressure ratings (W.P.) listed when operating at elevated temperatures.

Multiply the working pressure rating of the selected pipe at 73°F by the appropriate de-rating factor to determine the maximum working pressure rating of the pipe at the elevated temperature chosen.

EX: 6" PVC SCHEDULE 120
@ 130°F = ?
370 psi x 0.31 =
115 psi max. @ 130°F

De-Rating Factor

Operating Temp (°F)	De-Rating Factor
73	1.00
80	0.88
90	0.75
100	0.62
110	0.51
120	0.40
130	0.31
140	0.22

THE MAXIMUM SERVICE TEMPERATURE FOR PVC IS 140°F.

Solvent cemented joints should be utilized when working at or near maximum temperatures. Harvel Plastics does not recommend the use of PVC for threaded connections at temperatures above 110°F; use flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures.

Threading requires a 50% reduction in pressure rating stated for plain end pipe @73°F.

Chemical resistance data should be referenced for proper material selection and possible de-rating when working with fluids other than water. Refer to Harvel Plastics 112/401 Product Bulletin for chemical resistance and installation data.

Reference Harvel Plastics, Inc Product Bulletin 112/401 for information pertaining to chemical resistance, physical properties, joining methods, hangers and supports, collapse pressure ratings, system components and other system design and installation related data.

By permission, Harvel Plastics, Easton, PA.

1.12.0 Utility Pipe and Conduit Choices

The choices are wide and vary from aluminum and steel to lined pipe to plastics. Each type has somewhat different characteristics as well as installation and joining procedures.

1.12.1 Ductile Iron

Cast iron, a form of ductile iron, dates all the way back to 1455 when French King Louis XIV ordered the manufacture of a cast iron pipe to convey water from a pumping station to Versailles, 15 mi away. It remained in continuous service for 330 years, bearing testament to the longevity of this material.

Ductile iron is available for water working pressures greater than 350 psi.

1.12.1.1 Nominal Thickness for Standard Pressure Classes of Ductile Iron Pipe

DUCTILE IRON PIPE

Nominal Thicknesses for Standard Pressure Classes of Ductile Iron Pipe

Size in.	Outside Diameter in.	Pressure Class				
		150	200	250	300	350
		Nominal Thickness -- in.				
3	3.96	-	-	-	-	0.25*
4	4.80	-	-	-	-	0.25*
6	6.90	-	-	-	-	0.25*
8	9.05	-	-	-	-	0.25*
10	11.10	-	-	-	-	0.26
12	13.20	-	-	-	-	0.28
14	15.30	-	-	0.28	0.30	0.31
16	17.40	-	-	0.30	0.32	0.34
18	19.50	-	-	0.31	0.34	0.36
20	21.60	-	-	0.33	0.36	0.38
24	25.80	-	0.33	0.37	0.40	0.43
30	32.00	0.34	0.38	0.42	0.45	0.49
36	38.30	0.38	0.42	0.47	0.51	0.56
42	44.50	0.41	0.47	0.52	0.57	0.63
48	50.80	0.46	0.52	0.58	0.64	0.70
54	57.56	0.51	0.58	0.65	0.72	0.79
60	61.61	0.54	0.61	0.68	0.76	0.83
64	65.67	0.56	0.64	0.72	0.80	0.87

**Calculated thicknesses for these sizes and pressure ratings are less than those shown above. Presently these are the lowest nominal thicknesses available in these sizes.*

Pressure classes are defined as the rated water working pressure of the pipe in psi. The thickness shown above are adequate for the rated water working pressure plus a surge allowance of 100 psi. Calculations are based on a minimum yield strength in tension of 42,000 psi and 2.0 safety factor times the sum of working pressure and 100 psi surge allowance.

Courtesy of the Ductile Iron Pipe Research Association.

1.12.1.2 Pipe Joining Methods for Ductile Iron Pipe

Ductile Iron Pipe Joints and Their Uses

By Richard W. Bonds, P.E.
DIPRA Research and Technical Director

Introduction

Joints for Iron pipe have come a long way. About 550 years ago, the first Cast Iron pipes were made with flanged joints, using lead or leather gaskets. The bell and spigot joint, which was assembled by caulking yarn or braided hemp into the base of the annular bell cavity and then pouring molten lead into the remaining space inside the bell, was developed in 1785 and extensively used until the late 1950s. The roll-on joint was developed in 1937 and was used for roughly 20 years before its manufacture was discontinued. Assembly of this joint involved a compressed rubber gasket rolled under a restriction ring, followed by caulked square-braided jute. The remainder of the joint was packed with a bituminous compound.

Today, the push-on and mechanical joints are the most prominent. The mechanical joint was developed for gas industry use in the late 1920s but has since been used extensively in the water industry. The push-on joint was developed in 1956 and represented an important advancement in the water distribution field.

Several special joints have been available for years. These include ball and socket for subaqueous crossings, grooved and shouldered, and numerous variations of restrained joints.

There is a much wider variety of joints available for Ductile Iron pipe than any other piping material, providing greater flexibility and versatility in pipeline design and installation.

Push-On Joints

The most popular, quickest, and easiest-to-assemble joint for Ductile Iron pipe and fittings in underground applications is the push-on joint. This joint consists of a single rubber gasket placed in a groove inside the socket at the bell end of the pipe. After lubricating the joint in accordance with the manufacturer's instructions, the beveled end of the pipe is pushed past the gasket, compressing it and forming a pressure-tight and dependable seal. Step-by-step installation procedures can be found in ANSI/AWWA C600 "Installation of Ductile-Iron Water Mains and Their Appurtenances." Assembly of the push-on joint is simple and fast. Large bell holes are not required for this joint, and it can be assembled under wet-trench conditions or even underwater. The push-on joint has been tested to more than 1,000 psi internal pressure, 430 psi external pressure and 14 psi negative air pressure with no leakage or infiltration. Push-on joints of modern Ductile Iron pipe systems are particularly effective in preventing problems of infiltration, exfiltration, and root intrusion that have plagued sewer systems of other piping materials. Push-on joint performance requirements and push-on gasket manufacturing and performance requirements have been included in ANSI/AWWA C111/A21.11 "American National Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings" for many years.

Push-on Joints

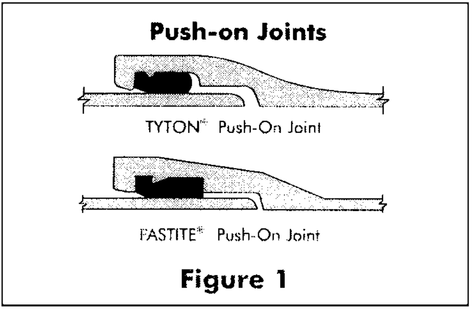


Figure 1

There are two types of push-on joints: the FASTITE®1 and TYTON®2 joints, which are shown in Figure 1. They differ somewhat in configuration, but both feature a gasket recess that is integrally cast into the bell of the pipe. The compression of the standard dual-hardness gasket results from the spigot being pushed home. The result is a flexible joint that is easy to assemble. Furthermore, the gasket is not easily dislodged or "rolled" during installation. Depending on pipe diameter, push-on joint Ductile Iron pipe has a joint deflection of up to 5° (Figure 2 and Table 1). This deflection enables the pipeline to be diverted from a straight line when following the curvature of streets and roads or when avoiding obstacles.

Pipeline Curve Geometry

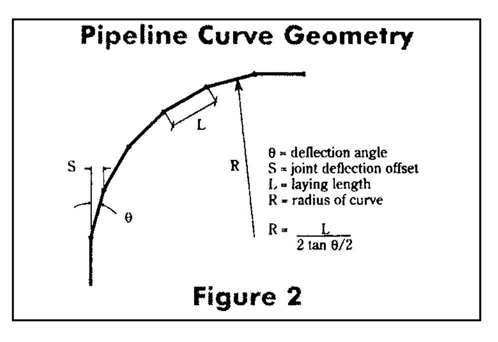


Figure 2

On long radius curves, the trench should be excavated wider than normal to allow for straight line assembly before deflection. Inserting the plain end of a full length of pipe into a socket under deflected conditions is not recommended and should be avoided if possible. When deflection is necessary, pipe should be assembled in a straight line, both horizontally and vertically, before deflection is made.

Reprint from the document *Ductile Iron Pipe Joints and Their Uses*. Courtesy of the Ductile Iron Pipe Research Association.

1.12.1.2 Pipe Joining Methods for Ductile Iron Pipe (Continued)

Mechanical Joint

The mechanical joint has standardized dimensions as specified in ANSI/AWWA C111/A21.11 "Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings." It is available for 3-inch through 24-inch-diameter Ductile Iron pipe manufactured in accordance with ANSI/AWWA C151/A21.51, and 3-inch through 48-inch fittings manufactured in accordance with ANSI/AWWA C110/A21.10 and C153/A21.53. The mechanical joint uses the basic principle of the stuffing box and gland developed nearly 100 years ago.

The joint has four parts: a flange cast with a bell; a rubber gasket that fits in the bell socket; a gland, or follower ring, to compress the gasket; and tee head bolts and nuts for tightening the joint (Figure 3). Joint assembly is labor-intensive but very simple and requires only one tool — an ordinary ratchet wrench. Step-by-step installation procedures can be found in ANSI/AWWA C600. The mechanical joint is flexible, with the amount of deflection dependent on pipe diameter (Table 2 and Figure 2). The mechanical joint is used mainly with fittings rather than pipe. This is due to the predominant use of push-on joints, which are more economical, faster to install, more trouble-free, and offer better service than mechanical joints.

Lubrication of the plain end, socket, and gasket during assembly of mechanical joint Ductile Iron pipe is recommended in ANSI/AWWA C111/A21.11, ANSI/AWWA C600, and manufacturers' literature. Based on controlled testing and extensive field experience, DIPRA concurs with this recommended lubrication with soapy water or approved pipe lubricant during mechanical joint assembly to improve gasket sealing and long-term performance.

Table 1

Maximum Deflection Full Length Pipe
Push-on Joint Pipe

Nominal Pipe Size (in.)	Deflection Angle - Ø* (deg.)	Max. Offset - S* (in.)		Approx. Radius of Curve - R* Produced by Succession of Joints (ft.)	
		L* = 18 ft.	L* = 20 ft.	L* = 18 ft.	L* = 20 ft.
3	5	19	21	205	230
4	5	19	21	205	230
6	5	19	21	205	230
8	5	19	21	205	230
10	5	19	21	205	230
12	5	19	21	205	230
14	3	11	12	340	380
16	3	11	12	340	380
18	3	11	12	340	380
20	3	11	12	340	380
24	3	11	12	340	380
30	3	11	12	340	380
36	3	11	12	340	380
42	3	11	12	340	380
48	3	-	12	-	380
54	3	-	12	-	380
60	3	-	12	-	380
64	3	-	12	-	380

Note: For 14-inch and larger push-on joints, maximum deflection may be larger than shown above. Consult your DIPRA member company.
** See Figure 2*

Mechanical Joint

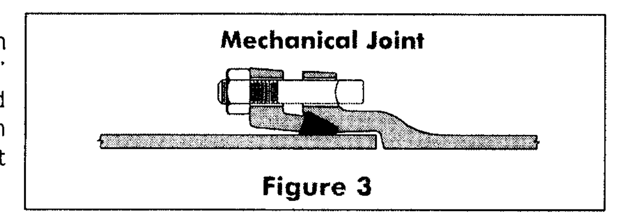


Figure 3

Flanged Joint

Although the flanged joint's first recorded application was more than 550 years ago, improved joints of this type are still used for many aboveground plant installations and other specialized applications (Figure 4). Flanged-joint Ductile Iron pipe is manufactured in accordance with ANSI/AWWA C115/A21.15 and is available in 3-inch through 64-inch diameters. Flanged fittings for 3-inch through 48-inch are manufactured in accordance with ANSI/AWWA C110/A21.10 and 54-inch through 64-inch are manufactured in accordance with ANSI/AWWA C153/A21.53.

Flanged joints for Ductile Iron pipe and fittings are rated for 250 psi working pressure. However, in accordance with ANSI/AWWA C111/A21.11, 24-inch and smaller flanged joints with Ductile Iron flanges may be rated for a maximum working pressure of 350 psi with the use of special gaskets.

Flanged piping systems should be installed in accordance with the suggested procedures listed in the appendices of ANSI/AWWA C110/A21.10, C115/A21.15 and C153/A21.53 Standards. Questions concerning gaskets should be directed to the manufacturer. For compatibility of these flanges with other standards, see DIPRA's brochure "Flanged Ductile Iron Pipe and Fittings."

Table 2

Maximum Deflection Full Length Pipe
Mechanical Joint Pipe

Nominal Pipe Size (in.)	Deflection Angle† - Ø* (deg.)	Max. Offset - S* (in.)		Approx. Radius of Curve - R* Produced by Succession of Joints (ft.)	
		L* = 18 ft.	L* = 20 ft.	L* = 18 ft.	L* = 20 ft.
3	8	31	35	125	140
4	8	31	35	125	140
6	7	27	30	145	160
8	5	20	22	195	220
10	5	20	22	195	220
12	5	20	22	195	220
14	3.5	13.5	15	285	320
16	3.5	13.5	15	285	320
18	3	11	12	340	380
20	3	11	12	340	380
24	2	9	10	450	500

† Rounded down to nearest half degree.
** See Figure 2*

Flanged Joint

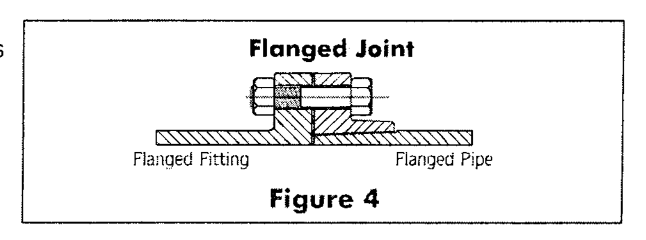


Figure 4

Reprint from the document *Ductile Iron Pipe Joints and Their Uses.* Courtesy of the Ductile Iron Pipe Research Association.

1.12.1.2 Pipe Joining Methods for Ductile Iron Pipe (Continued)

Restrained Joints

One big advantage of Ductile Iron pipe systems vs. alternate materials is the vast amount and variety of thrust restraint joint options. These restrained joints are used to resist thrust forces as an alternative to thrust blocking. A restrained joint is a special type of push-on or mechanical joint that is designed to provide longitudinal restraint. Restrained joint systems function in a manner similar to thrust blocks, insofar as the reaction of the entire restrained unit of piping with soil balances the thrust force. These special joints offer flexibility and are simply and quickly installed. Each manufacturer of Ductile Iron pipe holds patents on its own unique designs of these joints, and, therefore, the majority of restrained joints are considered proprietary.

Restrained joints are rated up to 350 psi working pressure for 4-inch- through 24-inch-diameter Ductile Iron pipe, and up to 250 psi working pressure for 30-inch through 64-inch. In some cases, restrained joints have been furnished for applications with far greater pressures. It is recommended that the manufacturer be consulted in such cases.

Push-On Restrained Joints

Push-on restrained joints are available in two basic types of designs: those with restrained push-on gaskets and specially designed push-on restrained joints.

Restrained Push-On Gasket

Restrained push-on gaskets have proven to be an extremely successful, trouble-free means of joint restraint for Ductile Iron pipe. These are patented gaskets that contain high-strength stainless steel elements spaced around the gasket that develop a dependable gripping action. Because of the wedging design, the force between the spigot and the socket of the pipe joint is essentially constant at any given pressure thrust regardless of the tightness or looseness of the joint fit or the joint deflection. Two configurations of this joint are shown in Figure 5.

Restrained Push-On Gasket Joints

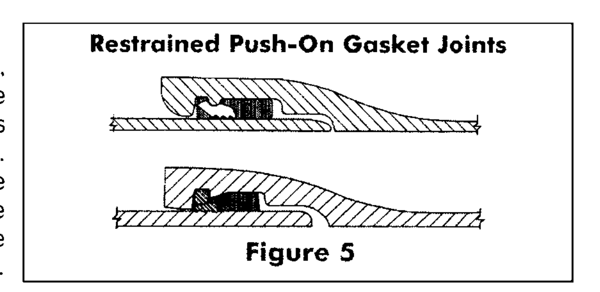


Figure 5

These push-on restrained joint gaskets are available for 4-inch through 30-inch-diameter Ductile Iron pipe. They are suitable for an allowable working pressure of up to 350 psi for 4-inch through 24-inch-diameter pipe and 150 psi for 30-inch.

These special gaskets are available for both the FASTITE® and TYTON® push-on joints. They have the same basic shape as the FASTITE® and TYTON® regular gaskets, so they can be used in any standard FASTITE® and TYTON® joint pipe. Therefore these gaskets may be used in lieu of standard push-on gaskets in the bells of standard push-on joint pipe, fittings, and valves where easy, field-adaptable restraint is desired. Note: FASTITE® and TYTON® gaskets, both standard and restrained gaskets, are not interchangeable.

Assembly is very similar to that of regular push-on joint pipe. Pipe cut in the field must be properly prepared prior to assembly. Contact pipe manufacturers for details on assembly and preparation of cut pipe.

Specially Designed Push-On Restrained Joints

Specially designed push-on restrained joints incorporate a push-on gasket and special bell designs in conjunction with their restraint mechanisms. The push-on gaskets used in these joints might not be interchangeable with the standard push-on gaskets. Contact the pipe manufacturer for details. Five configurations of this type joint are shown in Figure 6.

These types of specially designed push-on restrained joints are available for 4-inch- through 64-inch-diameter Ductile Iron pipe. They are suitable for an allowable working pressure of up to 350 psi for 4-inch- through 24-inch-diameter pipe and 250 psi for 30-inch through 64-inch.

In general, this type of joint is easily assembled by making a conventional push-on joint assembly and then inserting the Flex-Ring®, split ring, or ring segments (depending on design), extending the joint to remove any slack in the locking mechanism, and then setting the joint deflection as required. Each pipe manufacturer produces its own proprietary joints that have explicit installation instructions.

Specially Designed Push-On Restrained Joints

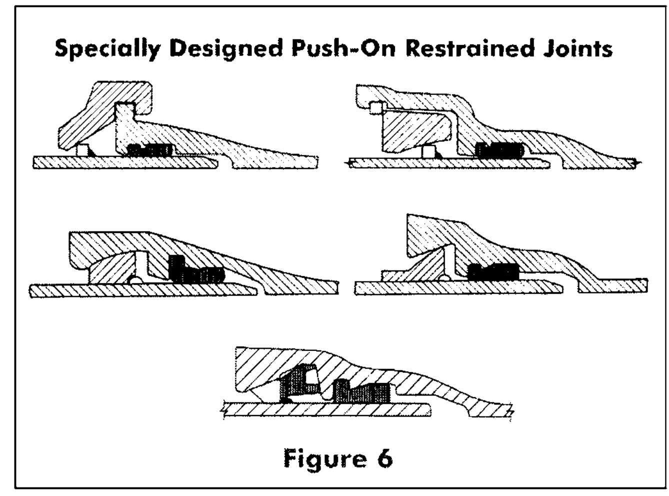


Figure 6

1.12.1.2 Pipe Joining Methods for Ductile Iron Pipe (Continued)

Mechanical Restrained Joints

Mechanical restrained joints offer a method of providing joint restraint with a standard mechanical joint socket of a pipe, fitting, valve, or other product. With the exception of some set-screw retainer glands, the tee-bolts for these joints are not standard length; special-length bolts are required for these joints. Three configurations of this type joint are shown in Figure 7.

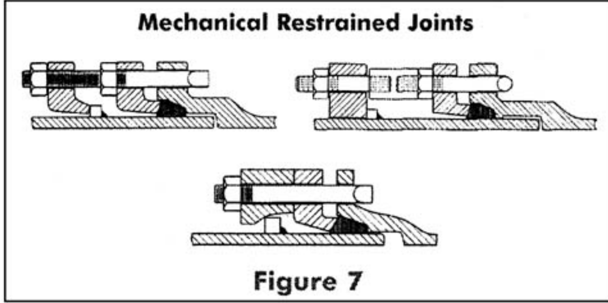

Mechanical Restrained Joints

Figure 7

Field-Welded Restrained Joints

Some restrained joints (push-on and mechanical) have a Ductile or alloy steel retainer ring welded around the circumference of the spigot of the pipe to provide a means of restraint. If one of these types of restrained joint pipe had to be cut in the field, a new ring would be required to be field welded around the new cut spigot. DIPRA and the manufacturers of Ductile Iron pipe offer technical papers outlining the procedure whereby Ductile Iron or alloy steel rings can be field welded onto the barrels of Ductile Iron pipe to be used in restrained joint applications.

In most instances, careful planning and/or measuring ahead to position required field cuts in unrestrained sections of a pipeline can eliminate the need for any field-fabricated restrained joints. Also, it is generally and technically preferable in restrained joint areas to restrain field-cut joints, when available, with restrained joints that only require a standard spigot end, which eliminates the need for field welding.

Ball and Socket Joints

Ductile Iron pipe with boltless ball and socket joints is an extremely versatile product for use in subaqueous construction. Important in this context are the extreme toughness of heavy Ductile Iron wall thicknesses and the flexibility and the restraint against joint separation provided by the ball and socket.

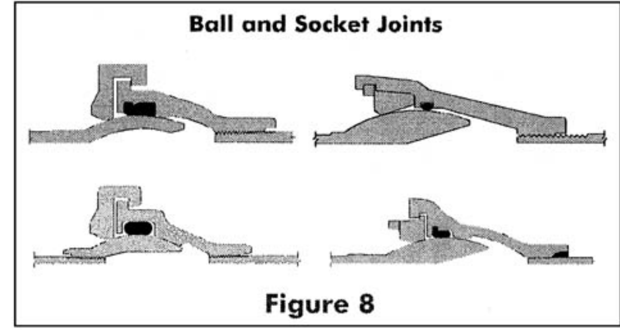

Ball and Socket Joints

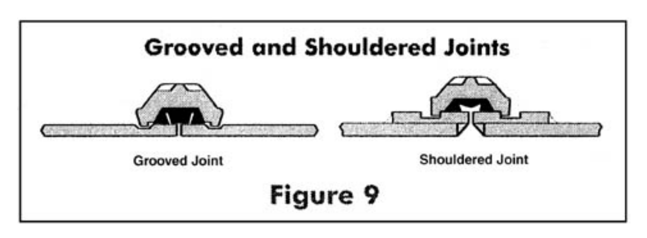
Figure 8

The ball and socket joints available for Ductile Iron pipe are boltless. They consist of a precision-machined ball that fits into a machined socket, a rubber gasket to provide a pressure-tight seal, and a retainer ring that provides longitudinal restraint. The joint is designed so that the rubber gasket is properly compressed and the joint is leak-free throughout the full range of deflection. Four configurations of this type joint are shown in Figure 8. Maximum deflection is 15° per joint in sizes up to and including 24-inch pipe; in sizes 30-inch and larger, maximum deflection varies from 12 ° to 15°. At maximum deflection, the joint remains pressure-tight and retains the full flow area available in the undeflected joint.

The versatility of the ball and socket pipe allows the installer to devise installation methods to accommodate the particular conditions of his job and equipment. Further discussion and general installation methods are presented in DIPRA's publication "Ductile Iron Pipe Subaqueous Crossings."

Grooved and Shouldered Joints

The grooved joint uses a bolted, segmental, clamp-type, mechanical coupling having a housing that encloses a U-shaped rubber gasket. The housing locks the pipe ends together and compresses the gasket against the outside of the pipe ends. The ends of the pipe are machine grooved to accept the housing. Grooved joints may be furnished as either rigid or flexible joints and are used mainly for aboveground applications. The shouldered joint is similar except that the pipe ends are shouldered instead of grooved. These joints in sizes 4-inch through 24-inch are covered in AWWA/ANSI C606, which defines material requirements, general design criteria, pipe-grooving details, and coupling test requirements. Two configurations of these type joints are shown in Figure 9.



Grooved and Shouldered Joints

Figure 9

Conclusion

Ductile Iron pipe has a wider variety of joints available than any other piping material. This gives Ductile Iron pipe greater versatility and flexibility in pipeline design and installation to accommodate the particular conditions on the drawing board and at the job site. These joints are time-proven to be strong, dependable, and bottletight. This is just one of the many reasons why utilities and consulting engineers know that Ductile Iron pipe is the right decision.

Note: Due to limited space, only a few select joints were shown in this article. For a complete assemblage of joints available for Ductile Iron pipe, see the Ductile Iron Pipe Research Association's "Installation Guide for Ductile Iron Pipe," and manufacturer's literature.

Reprint from the document *Ductile Iron Pipe Joints and Their Uses*. Courtesy of the Ductile Iron Pipe Research Association.

1.12.1.3 Linings Available for Ductile Iron Pipe

LININGS AVAILABLE FOR DUCTILE IRON PIPE & FITTINGS

Description	Maximum Service Temperature (°F)[1]	Uses	Thicknesses
Portland Cement Mortar[2] with Sealcoat without Sealcoat	 150° 212°	**Common:** Drinking Water Sea Water Non-Septic Gravity Sewers Sanitary Sewer Force Mains Reclaimed Water	Standard or Double (ANSI/AWWA C104/A21.4)
Fusion-Bonded Epoxy (Fittings Only)	120° - 150°[1]	**Common:** Drinking Water Non-Septic Gravity Sewers Sanitary Sewer Force Mains Reclaimed Water	See footnote 4 (ANSI/AWWA C116/A21.16)
Petroleum Asphalt Coating	150°	**Common:** Air	1 mil (nominal)
Ceramic Quartz Filled Amine Cured Novalac Epoxy[3]	120° - 150°[1]	**Common:** Septic Sewers Acids Alkali Waste Pickling Brine **Other Acceptable Services:** Reclaimed Water	40 mil (nominal)

[1]Maximum service temperatures listed are intended as general guidelines which may vary depending on service conditions and lining formulation. Consult pipe manufacturer for specific recommendations.

[2]ASTM C150 Type V sulfate resisting cement is recommended for seawater applications and some reclaimed water applications. Consult pipe manufacturer for specific reclaimed water recommendations.

[3]Consult pipe manufacturer for specific service use and material details.

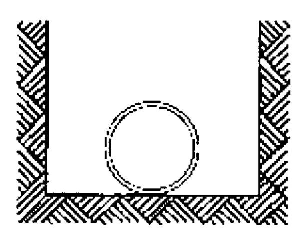
[4]Recommended lining thicknesses may vary depending on service conditions, epoxy formulation, diameter, and other variables. Consult fitting manufacturer for specific recommendations.

Courtesy of the Ductile Iron Pipe Research Association.

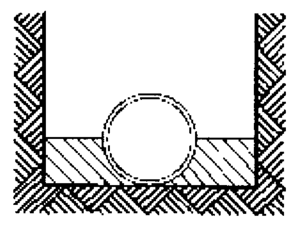
1.12.1.4 Laying Conditions for Ductile Iron Pipe

DUCTILE IRON PIPE

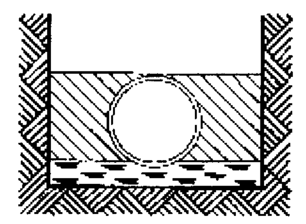
Standard Laying Conditions for Ductile Iron Pipe



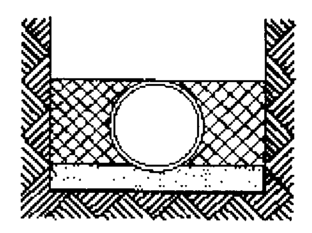
Type 1*
Flat-bottom trench.** Loose backfill.



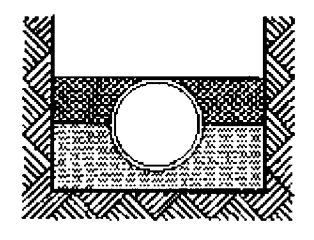
Type 2
Flat-bottom trench.** Backfill lightly consolidated to centerline of pipe.



Type 3
Pipe bedded in 4-inch minimum loose soil.*** Backfill lightly consolidated to top of pipe.



Type 4
Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-inch minimum. Backfill compacted to top of pipe. (Approximately 80% Standard proctor, AASHTO T-99.)



Type 5
Pipe bedded to its centerline in compacted granular material, 4-inch minimum under pipe. Compacted granular or select material*** to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99.)

***For 14-inch and larger pipe, consideration should be given to the use of laying conditions other than Type 1.**

****"Flat-bottom" is defined as "undisturbed earth."**

Courtesy of the Ductile Iron Pipe Research Association.

Cement-mortar lined ductile iron pipe meets ANSI/AWWA C104/A21.4 specifications for water service and for some sewage service. The cement lining provides protection against interior pipe corrosion and exhibits improved flow characteristics.

1.13.3 Thermoplastic Pipe

Plastic pipe has application in residential, commercial, and industrial use for storm and sanitary drainage and vent lines. Grades are Schedule 40DWV pipe, usually referred to simply as Schedule 40, for both aboveground and below-ground applications. A special 3.25-in. outside-diameter pipe with a thinner wall than Schedule 40 is also available and is Schedule 30, usually used when there are space limitations such as installation in a 2 × 4 nominal thickness stud wall.

Schedule 80 PVC pipe has a thicker wall section and is applicable for pressure ratings of 210 to 1230 psi and temperatures up to and including 140°F. Schedule 120, available in pipe diameters from ½ to 8 in., can withstand pressures between 380 and 1010 psi.

1.13.4 General Properties of Thermoplastic Pipe

Poly(vinyl chloride) (PVC)

This plastic has the broadest range of applications in piping systems and its use has grown more rapidly than that of other plastics. PVC has good chemical resistance to a wide range of corrosive fluids, but may be damaged by ketones, aromatic and some chlorinated hydrocarbons (Table I). There are two principal types of PVC used in the manufacture of pipe and fittings, Type I and Type II (ASTM D 1784). Type I, also called unplasticized or rigid PVC, contains a minimum of processing aids and other additives and has maximum tensile and flexural strength, modulus of elasticity, and chemical resistance; however, it is more brittle. It also has a maximum service temperature under stress of about 65°C (150°F), lower thermal expansion than Type II, and does not support combustion. Type II PVC, which is modified with rubber to render it less rigid and tougher, is also called high-impact, flexible or non-rigid PVC. It has lower tensile and flexural strength, lower modulus of elasticity, lower heat stability and less chemical resistance than Type I. The improvements made through research and the availability of product standards for special uses have increased its acceptance by designers, contractors and building code officials[2-4]. PVC pipe is available in both schedule number, which is determined by the expression 1000 x P/S, where P is the service temperature and S, the allowable stress (both expressed in the same units) and standard dimension (SDR) sizes, obtained by dividing the outside diameter of the pipe by its wall thickness. It is used in drain-waste-vent (DWV) applications, in storm, sanitary, water-main, and natural gas distribution, and in industrial and process piping. The fastest growing application in North America is currently for municipal water and sewerage systems. PVC pipe is also used as a conduit for wiring (both electrical and communications).

Chlorinated PVC (CPVC)

The basic resin in this plastic is made by post-chlorination of PVC. CPVC has essentially the same properties as Type I PVC material, but has the added advantage of withstanding temperatures up to 100° C (212°F), approximately 33 deg C (59 deg F) more than PVC plastic. Although it is suitable for the same piping applications as Type I PVC, the higher cost of CPVC restricts its use to that of conveying hot fluids. A plumbing system in which CPVC pipe of the same diameter as copper pipe is used for water distribution lines can handle 690 kPa (100 psi) working pressure at 82°C (180°F). Consequently, CPVC pipe is now replacing copper pipe in many areas of Europe and the U.S.A.

Polyethylene (PE)

Pipe made from PE has a relatively low mechanical strength (Table II), but exhibits good chemical resistance and flexibility and is generally satisfactory for use at temperatures below 50°C (122°F). The temperature limitation is, however, offset by good flexibility retention down to -55°C (-67°F). Polyethylene piping plastics are classified into three types on the basis of density: low density (Type I), medium density (Type II) and high density (Type III). The most popular are Types II and III. The mechanical strength, chemical resistance and temperature resistance increase with density, whereas creep diminishes as the density increases.

PE pipe is available in both schedule number and standard dimension (SDR) sizes. Its principal applications are: irrigation and sprinkler systems, drainage, chemical transport, gas distribution pipe and electrical conduit systems.

Source: National Research Council of Canada.

1.13.4 General Properties of Thermoplastic Pipe (Continued)

Table II. Typical properties* of common thermoplastic pipe materials.

Type of Plastic	Density, g/cm³ (ASTM D 792)	Coefficient of Thermal Expansion, 10^{-6}/°C (ASTM D 696)	Thermal Conductivity $W \cdot m^{-1} \cdot °C^{-1}$ ($Btu \cdot in \cdot h^{-1} \cdot ft^{-2} \cdot °F^{-1}$) (ASTM D 177)	Heat Deflection Temperature, °C(°F), under 182 MPa (264 psi) (ASTM D 648)	Tensile Strength, MPa (psi) (ASTM D 638)	Compressive Strength, MPa (psi) (ASTM D 695)	Flexural Strength, MPa (psi) (ASTM D 790)	Modulus of Elasticity, GPa (10^5·psi) (ASTM D 638)
PVC	1.38	50	0.16 (1.1)	74 (165)	48.3 (7,000)	62.2 (9,600)	99.8 (14,500)	3.1(4.5)
CPVC	1.54	79	0.14 (0.96)	102 (216)	50.3 (7,300)	106.9 (15,500)	99.8 (14,500)	2.5 (3.6)
PE (UHMW)	0.95	149	0.50 (3.5)	77 (171)	23.4 (3,400)	--	19.3 (2,800)	0.48 (0.70)
PE**	0.92-0.95	130-180	0.33-0.50 (2.3-3.5)	--	12.0-19.3 (1,750-2,800)	--	11.7-13.8 (1,700-2,000)	1.4-10 (0.20-1.5)
ABS	1.04	101	0.20 (1.4)	92 (198)	37.9 (5,500)	53.1 (7,700)	68.9 (10,000)	2.1 (3.1)
PP	0.91	68	0.19 (1.3)	66 (151)	33.8 (4,900)	58.6 (8,500)	58.6 (8,500)	1.0 (1.5)

* These data represent average values; pipe materials differ in properties, depending on formulation and manufacturing process (6).
** Low, medium and high density (Type II and Type III).

Specialty PE Pipes

A relatively new development in PE piping is the introduction of ultrahigh molecular weight (UHMW) PE and cross-linked PE plastic piping materials. The UHMW PE has considerably higher resistance to stress-cracking but is more costly than conventional PE piping material. It offers an extra margin of safety when used in sustained pressure conditions in comparison with pipe made from lower molecular weight resin. It is suitable for certain applications in the chemical industry where stress-cracking resistance has been a limiting factor for the conventional PE pipe.

Cross-linked PE piping material, when compared to ordinary PE pipe, displays greater strength, higher stiffness and improved resistance to abrasion and to most chemicals and solvents at elevated temperatures up to 95°C (203°F). Pipe made from cross-linked PE also has high-impact resistance even at sub-zero temperatures. It is used in applications too severe for ordinary PE pipe. The joining technique used is threading.

Acrylonitrile-butadiene-styrene (ABS)

ABS plastic is a copolymer made from the three monomers described in the heading, and contains at least 15 per cent of acrylonitrile. It is a rigid plastic with good impact resistance at lower temperatures down to -40°C (-40°F) and can be used at temperatures up to 80°C (176°F). ABS is utilized mainly for drain-waste-ventilation (DWV) pipe and fittings but it is also used in solvent cement for installing pipe in various applications. ADS pipe can be joined by solvent welding or threading.

A new development in the ABS-DWV piping industry is the co-extruded foam-core ABS pipe. It consists of a foam core sandwiched between solid skins and can be used for sewer, conduit and duct pipe. The foam-core pipe, with its lower resin requirements, could make ABS more price-competitive with existing materials in these applications.

Source: National Research Council of Canada.

1.13.4 General Properties of Thermoplastic Pipe (Continued)

Polybutylene (PB)

Polybutylene piping has practically no creep and has excellent resistance to stress cracking. It is flexible, and in many respects similar to Type III polyethylene, but is stronger. Polybutylene plastic piping is relatively new, and thus far its use has been limited to the conveyance of natural gas and to water distribution systems. Its high temperature grade can resist temperatures of 105-110°C (221-230°F).

Polypropylene (PP)

Polypropylene-based piping is the lightest-weight plastic material (density = 0.90 g/cm^3) and generally has better chemical resistance than other plastics. PP is used in some pressure piping applications, but its primary use is in low pressure lines. Polypropylene plastic pipe is used for chemical (usually acid) waste drainage systems, natural-gas and oil-field systems, and water lines. The maximum temperature for non-pressure piping is 90°C (194°F). Pipe lengths are joined by heat fusion, threading (i.e., with heavy pipe) and mechanical seal devices.

Other thermoplastics

Other thermoplastics used in the manufacture of pipe include poly(vinylidene chloride), poly (vinylidene fluoride), cellulose acetate butyrate (CAB), acetal homopolymer resins, rubber-modified systems, polytetrafluoroethylene (PTFE), and fluorinated ethylene-propylene (FEP) copolymer. All of these materials are relatively expensive and are used only for very special applications.

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Source: National Research Council of Canada.

1.13.5 Thermoplastic Pipe Deflection and Expansion

The installation of thermoplastic pipe should take into account two factors: deflection, and expansion and contraction. The expansion of thermoplastic pipe per 100 ft is significantly higher than metal with high-density polyethylene (HDPE) and much higher than PVC and CPVC. When it is installed aboveground, provisions must be made for expansion and contraction via an expansion loop.

1.13.6 PVC and CPVC Expansion Loops and Offsets

PVC Expansion Loops

PVC		Length of Run (feet)									
		10	20	30	40	50	60	70	80	90	100
Pipe Size (in.)	O.D. of Pipe (in.)	Minimum Deflected Pipe Length (DPL) (inches)									
1/2	0.840	11	15	19	22	24	27	29	31	32	34
3/4	1.050	12	17	21	24	27	30	32	34	36	38
1	1.315	14	19	23	27	30	33	36	38	41	43
1 1/4	1.660	15	22	26	30	34	37	40	43	46	48
1 1/2	1.900	16	23	28	33	36	40	43	46	49	51
2	2.375	18	26	32	36	41	45	48	51	55	58
3	3.500	22	31	38	44	49	54	58	62	66	70
4	4.500	25	35	43	50	56	61	66	71	75	79
6	6.625	30	43	53	61	68	74	80	86	91	96
8	8.625	35	49	60	69	78	85	92	98	104	110
10	10.750	39	55	67	77	87	95	102	110	116	122
12	12.750	42	60	73	84	94	103	112	119	127	133

PVC Offsets and Change of Directions

PVC		Length of Run (feet)									
		10	20	30	40	50	60	70	80	90	100
Pipe Size (in.)	O.D. of Pipe (in.)	Minimum Deflected Pipe Length (DPL) (inches)									
1/2	0.840	15	22	27	31	34	37	41	43	46	48
3/4	1.050	17	24	30	34	38	42	45	48	51	54
1	1.315	19	27	33	38	43	47	51	54	57	61
1 1/4	1.660	22	30	37	43	48	53	57	61	65	68
1 1/2	1.900	23	33	40	46	51	56	61	65	69	73
2	2.375	26	36	45	51	58	63	68	73	77	81
3	3.500	31	44	54	62	70	77	83	88	94	99
4	4.500	35	50	61	71	79	87	94	100	106	112
6	6.625	43	61	74	86	96	105	114	122	129	136
8	8.625	49	69	85	98	110	120	130	139	147	155
10	10.750	55	77	95	110	122	134	145	155	164	173
12	12.750	60	84	103	119	133	146	158	169	179	189

Figure A: Guided Cantilever Beam

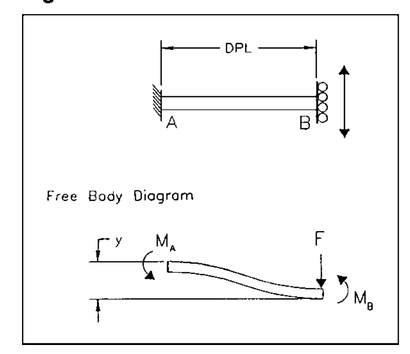
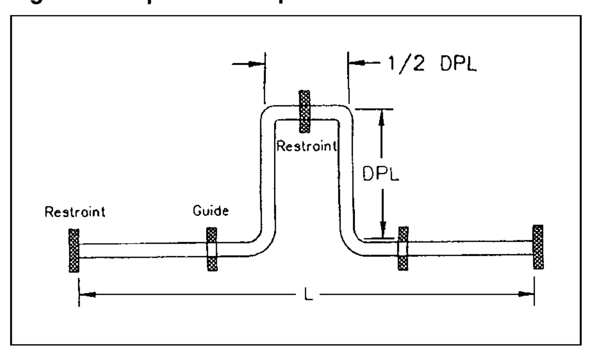


Figure B: Expansion Loop



1.13.6 PVC and CPVC Expansion Loops and Offsets (Continued)

CPVC Expansion Loops

CPVC		Length of Run (feet)									
		10	20	30	40	50	60	70	80	90	100
Pipe Size (in.)	O.D. of Pipe (in.)	Minimum Deflected Pipe Length (DPL) (inches)									
1/2	0.840	15	21	26	30	33	36	39	42	44	47
3/4	1.050	17	23	29	33	37	40	44	47	50	52
1	1.315	18	26	32	37	41	45	49	52	55	58
1 1/4	1.660	21	29	36	42	46	51	55	59	62	66
1 1/2	1.900	22	31	39	44	50	54	59	63	67	70
2	2.375	25	35	43	50	56	61	66	70	75	79
3	3.500	30	43	52	60	67	71	80	85	91	95
4	4.500	34	4	59	68	77	84	91	97	103	108
6	6.625	42	59	72	83	93	102	110	117	125	131
8	8.625	47	67	82	95	106	116	125	134	142	150
10	10.750	53	75	92	106	118	130	140	150	159	167
12	12.750	58	81	100	115	129	141	152	163	173	182

CPVC Offsets and Change of Directions

CPVC		Length of Run (feet)									
		10	20	30	40	50	60	70	80	90	100
Pipe Size (in.)	O.D. of Pipe (in.)	Minimum Deflected Pipe Length (DPL) (inches)									
1/2	0.840	21	30	36	42	47	51	55	59	63	66
3/4	1.050	23	33	40	47	22	57	62	66	70	74
1	1.315	26	37	45	52	58	61	69	74	78	83
1 1/4	1.660	29	42	51	59	66	72	78	86	88	93
1 1/2	1.900	31	44	54	63	70	77	83	89	94	99
2	2.375	35	50	61	70	79	86	93	99	105	111
3	3.500	43	60	74	85	95	105	113	121	128	135
4	4.500	48	68	84	97	108	119	128	137	145	153
6	6.625	59	53	102	117	131	144	155	166	176	186
8	8.625	67	95	116	134	150	164	177	189	201	212
10	10.750	75	106	130	150	167	183	198	212	224	237
12	12.750	81	115	141	163	182	200	216	230	244	258

Figure C: Expansion Offset

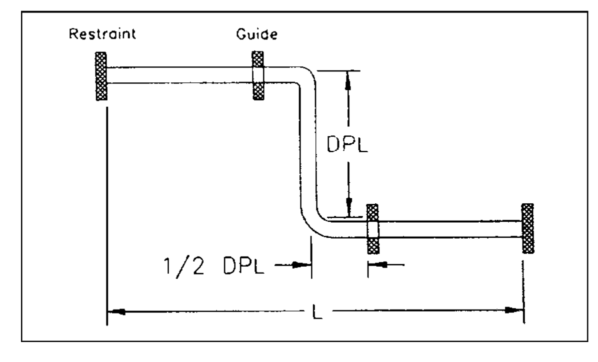
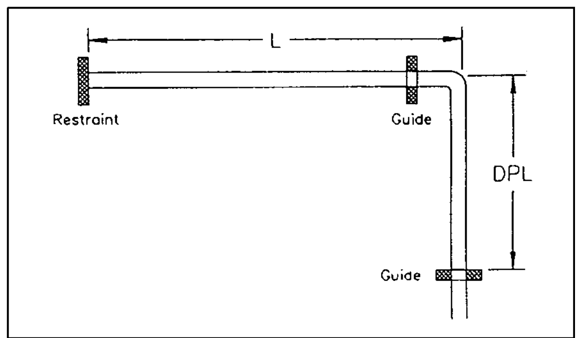


Figure D: Change of Direction



1.14.0 Concrete Pipe

Precast concrete pipe has many advantages:

- High quality during production results in a watertight envelope, and with standard gaskets sealant formulated to adhere to concrete, the drainage system using concrete pipe that watertight integrity is possible.
- Because this type of pipe is manufactured and stockpiled locally in most major urban areas, it is readily available.
- Concrete pipe has a specific gravity of 2.40 and resists buoyancy when installed underground.
- Concrete pipe is fire-resistant.
- The modular nature of pipe manufacture makes assembly of concrete pipe relatively easy.
- It has long life—installation for a 100-year life is feasible using concrete pipe.

1.14.1 Dimensions and Approximate Weight of Reinforced Concrete Pipe

ASTM C 76
Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, Tongue and Groove Joints

	WALL A		WALL B		WALL C	
Internal Diameter, inches	Minimum Wall Thickness, inches	Approximate Weight, pounds per foot	Minimum Wall Thickness, inches	Approximate Weight, pounds per foot	Minimum Wall Thickness, inches	Approximate Weight, pounds per foot
12	1¾	79	2	93	–	–
15	1⅞	103	2¼	127	–	–
18	2	131	2½	168	–	–
21	2¼	171	2¾	214	–	–
24	2½	217	3	264	3¾	366
27	2⅝	255	3¼	322	4	420
30	2¾	295	3½	384	4¼	476
33	2⅞	336	3¾	451	4½	552
36	3	383	4	524	4¾	654
42	3½	520	4½	686	5¼	811
48	4	683	5	867	5¾	1011
54	4½	864	5½	1068	6¼	1208
60	5	1064	6	1295	6¾	1473
66	5½	1287	6½	1542	7¼	1735
72	6	1532	7	1811	7¾	2015
78	6½	1797	7½	2100	8¼	2410
84	7	2085	8	2409	8¾	2660
90	7½	2395	8½	2740	9¼	3020
96	8	2710	9	3090	9¾	3355
102	8½	3078	9½	3480	10¼	3760
108	9	3446	10	3865	10¾	4160

Large Sizes of Pipe Tongue and Groove Joint

Internal Diameter Inches	Internal Diameter Feet	Wall Thickness Inches	Approximate Weight, pounds per foot
114	9½	9½	3840
120	10	10	4263
126	10½	10½	4690
132	11	11	5148
138	11½	11½	5627
144	12	12	6126
150	12½	12½	6647
156	13	13	7190
162	13½	13½	7754
168	14	14	8339
174	14½	14½	8945
180	15	15	9572

These tables are based on concrete weighing 150 pounds per cubic foot and will vary with heavier or lighter weight concrete.

Source: American Concrete Pipe Association.

1.14.1 Dimensions and Approximate Weight of Reinforced Concrete Pipe (Continued)

ASTM C76—Reinforced Concrete Culvert, Storm Drain and Sewer Pipe, Bell and Spigot Joint.				
Internal Diameter, inches	Wall A		Wall B	
	Minimum Wall Thickness, inches	Average Weight, pounds per foot	Minimum Wall Thickness, inches	Average Weight, pounds per foot
12	1-3/4	90	2	106
15	1-7/8	120	2-1/4	148
18	2	155	2-1/2	200
21	2-1/4	205	2-3/4	260
24	2-1/2	265	3	325
27	2-5/8	310	3-1/4	388
30	2-3/4	363	3-1/2	459

These tables are based on concrete weighing 150 pounds per cubic foot and will vary with heavier or lighter weight concrete.

1.14.2 Dimensions and Approximate Weight of Nonreinforced Concrete Pipe

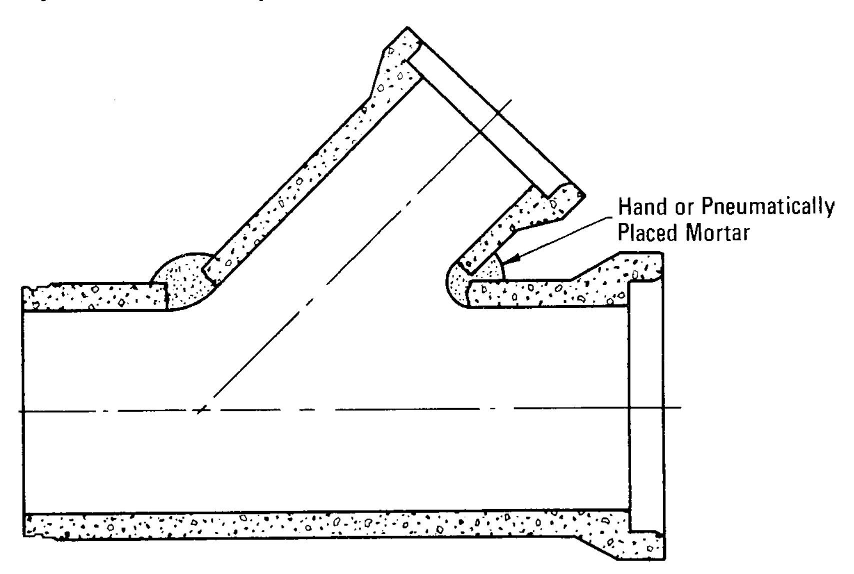
ASTM C14—Nonreinforced Sewer and Culvert Pipe, Bell and Spigot Joint						
Internal Diameter, inches	Class 1		Class 2		Class 3	
	Minimum Wall Thickness, inches	Average Weight, pounds per foot	Minimum Wall Thickness, inches	Average Weight, pounds per foot	Minimum Wall Thickness, inches	Average Weight, pounds per foot
4	5/8	9.5	3/4	13	3/4	13
6	5/8	17	3/4	20	7/8	21
8	3/4	27	7/8	31	1-1/8	36
10	7/8	37	1	42	1-1/4	50
12	1	50	1-3/8	68	1-3/4	90
15	1-1/4	78	1-5/8	100	1-7/8	120
18	1-1/2	105	2	155	2-1/4	165
21	1-3/4	159	2-1/4	205	2-3/4	260
24	2-1/8	200	3	315	3-3/8	350
27	3-1/4	390	3-3/4	450	3-3/4	450
30	3-1/2	450	4-1/4	540	4-1/4	540
33	3-3/4	520	4-1/2	620	4-1/2	620
36	4	580	4-3/4	700	4-3/4	700

Source: American Concrete Pipe Association.

1.14.3 Concrete Pipe Fittings—Ts and Ys

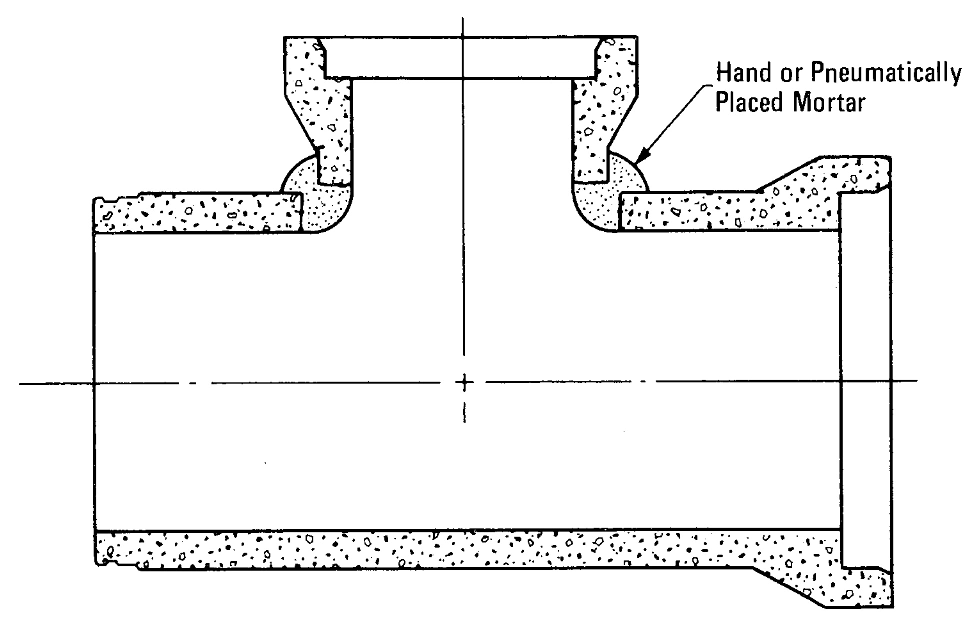
Wyes are similar to tees except the centerline of the intersecting pipe intersects the centerline of the-base pipe at an acute angle. Wyes are also utilized to effect the junction of two pipelineswithout the necessity of a manhole or junction chamber.Wyes are commonly used to connect build-ing sewers or house laterals to a sewer main.

Wyes for Concrete Pipe



By permission, American Concrete Pipe Association, Irving, Texas.

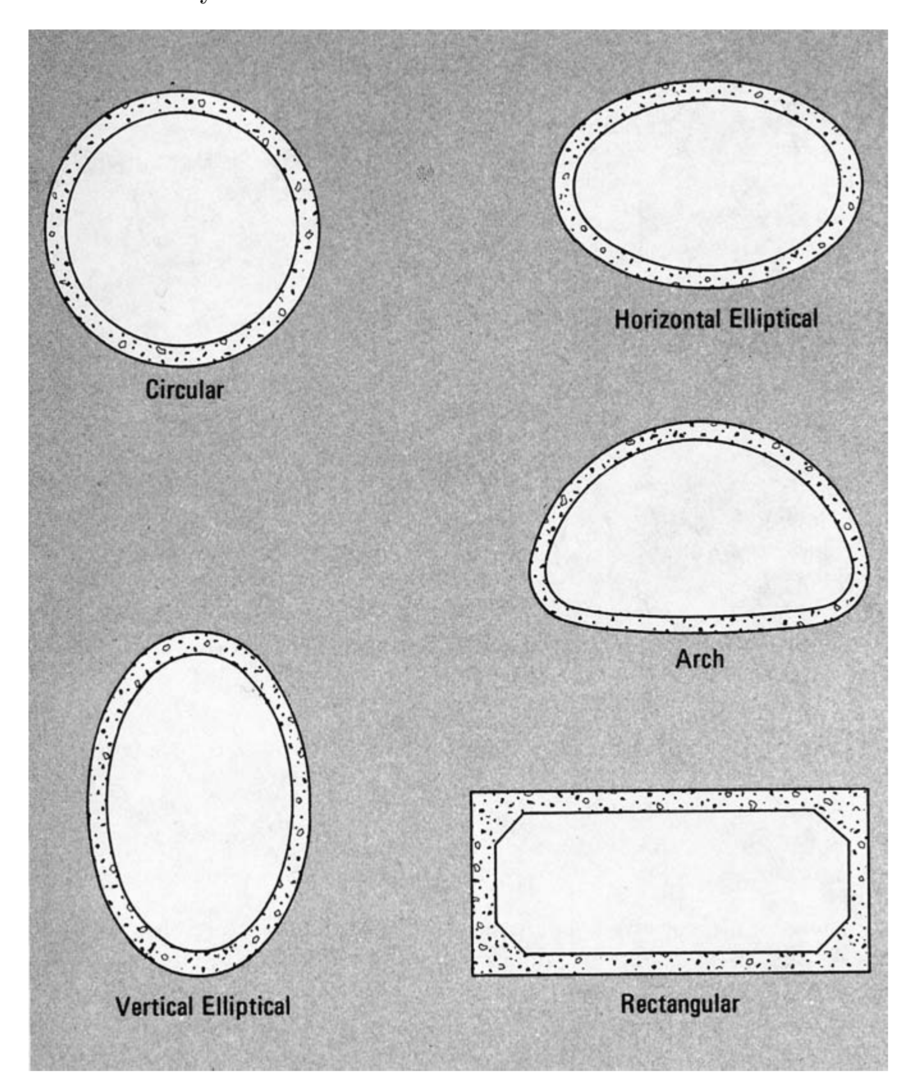
Concrete Pipe Tee



By permission, American Concrete Pipe Association, Irving, Texas.

1.14.4 Concrete Pipe Configurations

Concrete pipe is manufactured in five common shapes. Regional custom and demand usually determine availability.

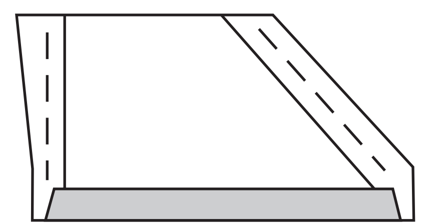


Source: American Concrete Pipe Association.

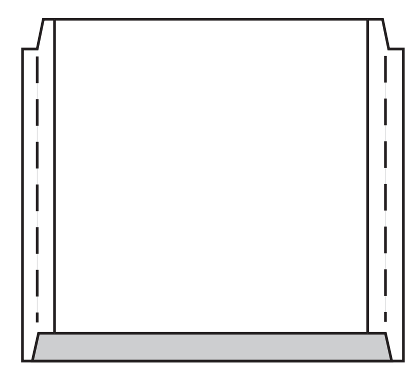
1.15.0 Typical Precast Concrete Manhole Components



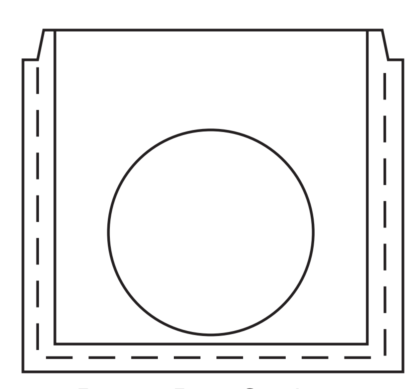
Grade Ring



Eccentric Cone Section



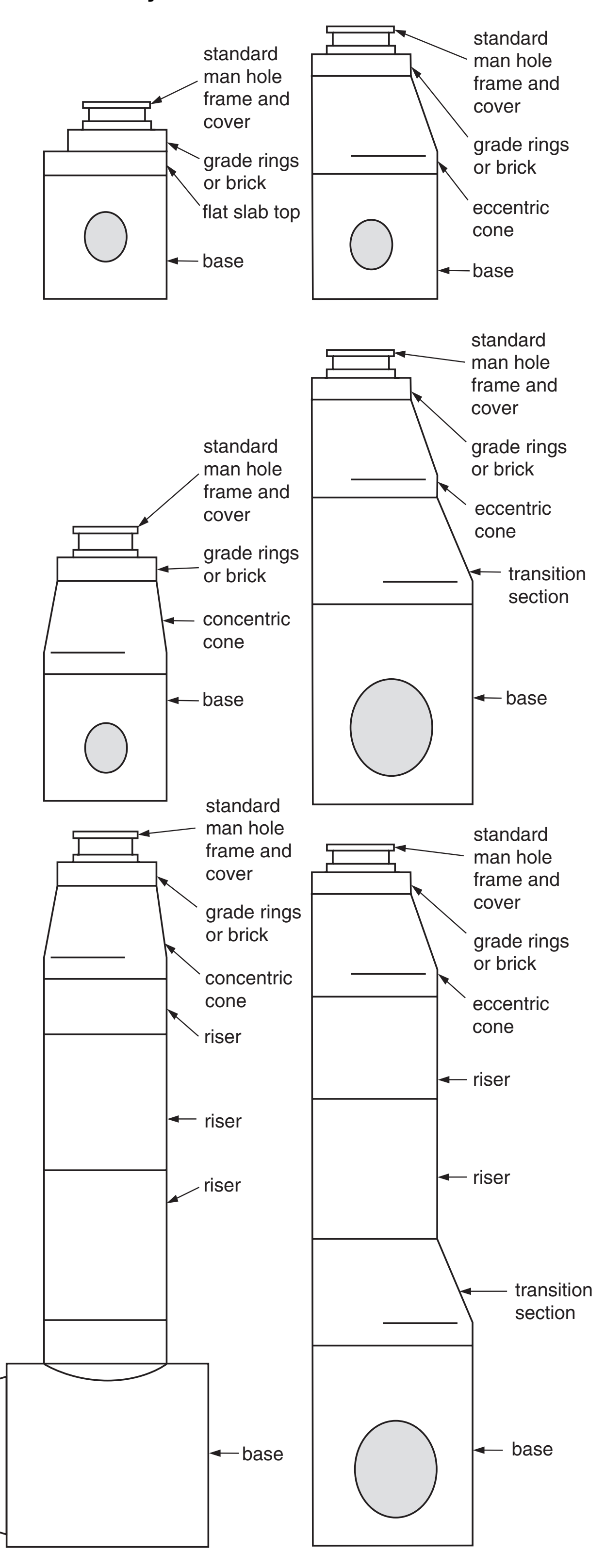
Riser Section



Precast Base Section

Source: American Concrete Pipe Association.

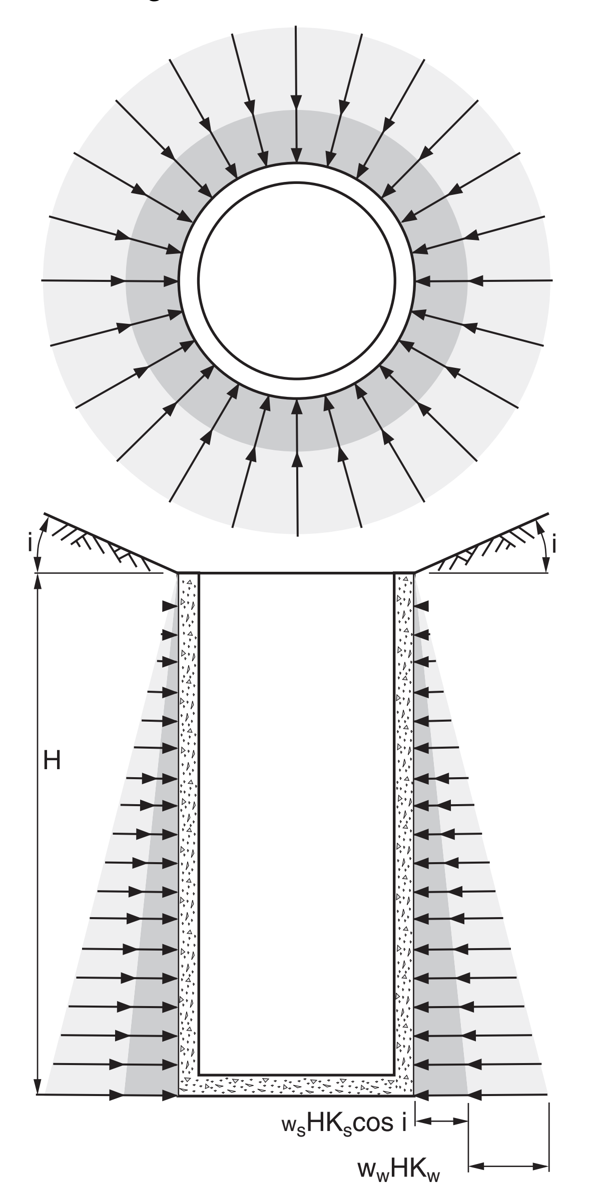
1.15.1 Typical Assembly Combinations



Specific information concerning precast concrete manhole assemblies to meet individual project requirements is available from any member company of theAmerican Concrete Pipe Association.

Source: American Concrete Pipe Association.

1.15.2 Forces Acting on Circular Concrete Riser Sections



FORCES ON CIRCULAR MANHOLE RISER SECTIONS

A circular precast concrete riser is the ideal material for constructing a vertical buried structure. Manhole riser sections have a thick high-strength concrete wall that easily resists the compressive forces caused by lateral earth and hydrostatic pressure. The mass of the concrete gives the structure stability in buoyant installation conditions. See Design Data 22 Flotation of Circular Concrete Pipe, for additional information on the effect of buoyancy on buried structures.

Lateral earth pressure. Because manhole risers are manufactured in standard diameters with the minimum wall thickness directly proportional to the riser diameter, a general vertical depth limit for all sizes may be calculated. The most severe loading condition on a riser section occurs when the ground water elevation is the same as the surface of the ground. The forces acting on the riser section are illustrated in Figure 2. The total active force consists of two components; active lateral earth pressure and hydrostatic pressure. Both components of the load act in a radial direction and are distributed uniformly around the periphery of the manhole. Radial forces acting on a circular cross-section result in only compressive forces on the section. There are no bending forces in a riser section unless there is a discontinuity such as a hole for a sewer pipe connection.

Based on the radial load distribution, the lateral earth pressure and hydrostatic pressure at any depth within the soil mass is given by the following equation:

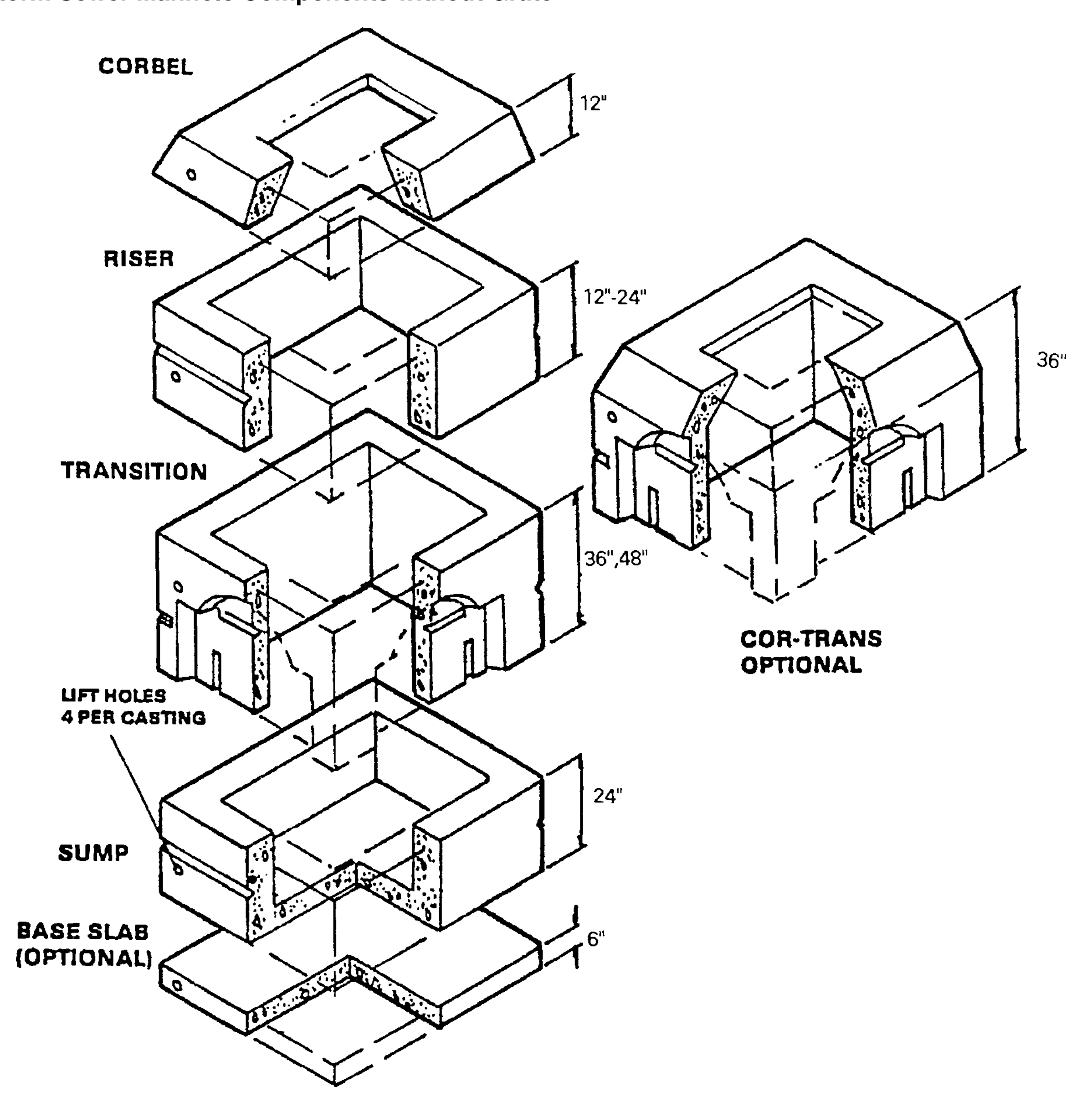
$$p = w_s H K_s \cos i + w_w H K_w \qquad (1)$$

where:
- p = total earth and hydrostatic pressure, pounds per square foot
- w_s = effective unit weight of backfill material, pounds per cubic feet
- H = depth of manhole, feet
- K_s = conjugate ratio for soil
- i = angle between backfill surface and the horizontal, degrees
- w_w = unit weight of water, pounds per cubic feet
- K_w = conjugate ratio for water

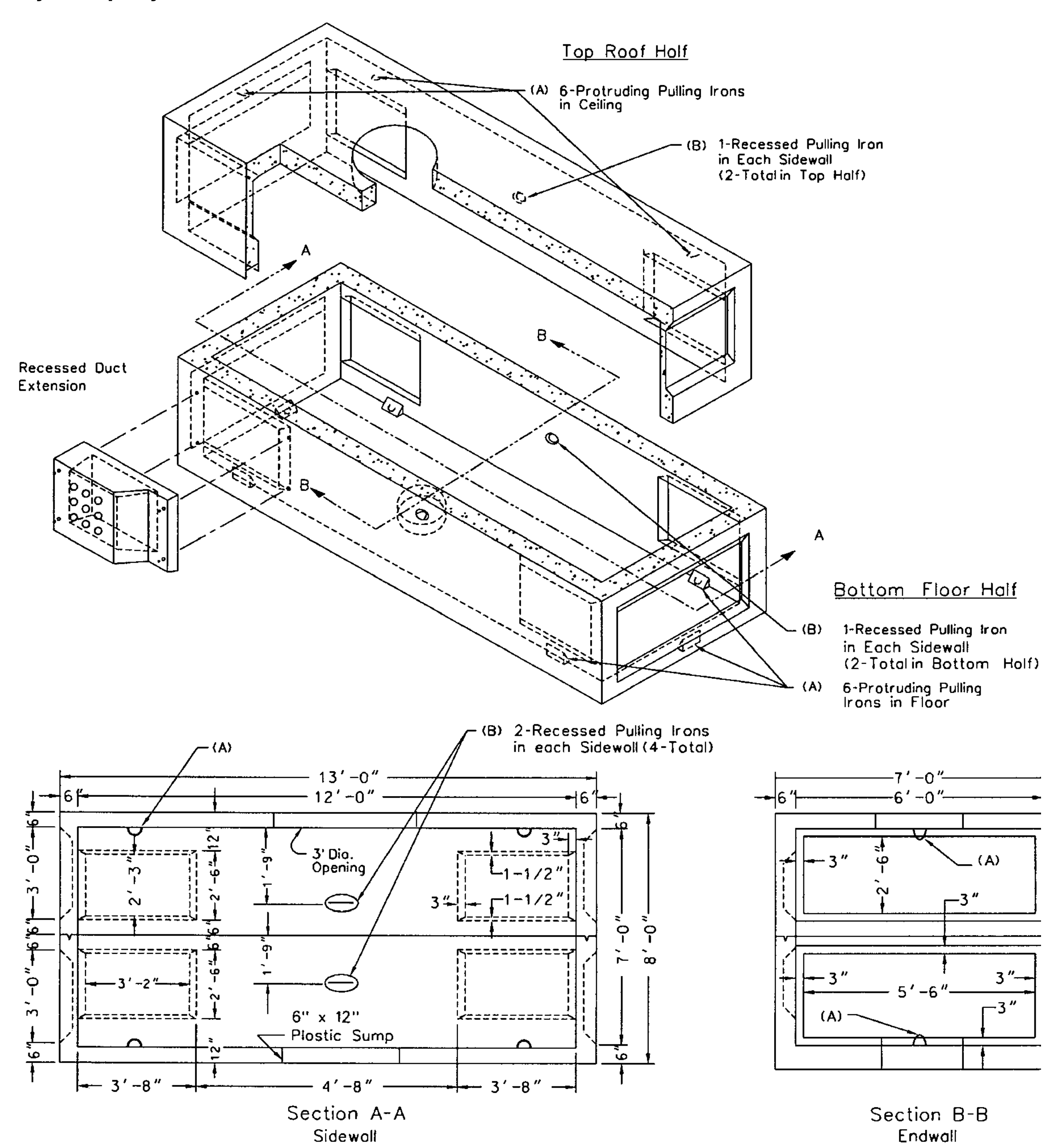
In most cases, the ground surface is level and i = zero degrees. Therefore cos i = 1.0 and equation (1) becomes:

Source: American Concrete Pipe Association.

1.15.3 Storm Sewer Manhole Components without Grate



1.16.0 Utility Company Precast Electric Manhole



Notes: (A) Install approved protruding pulling irons in the ceiling and floor. Center pulling irons at endwalls and at sidewalls opposite duct knockouts (12-total).

(B) Install approved recessed pulling irons in bottom half and top half of manhole. Center in sidewall (4-total).

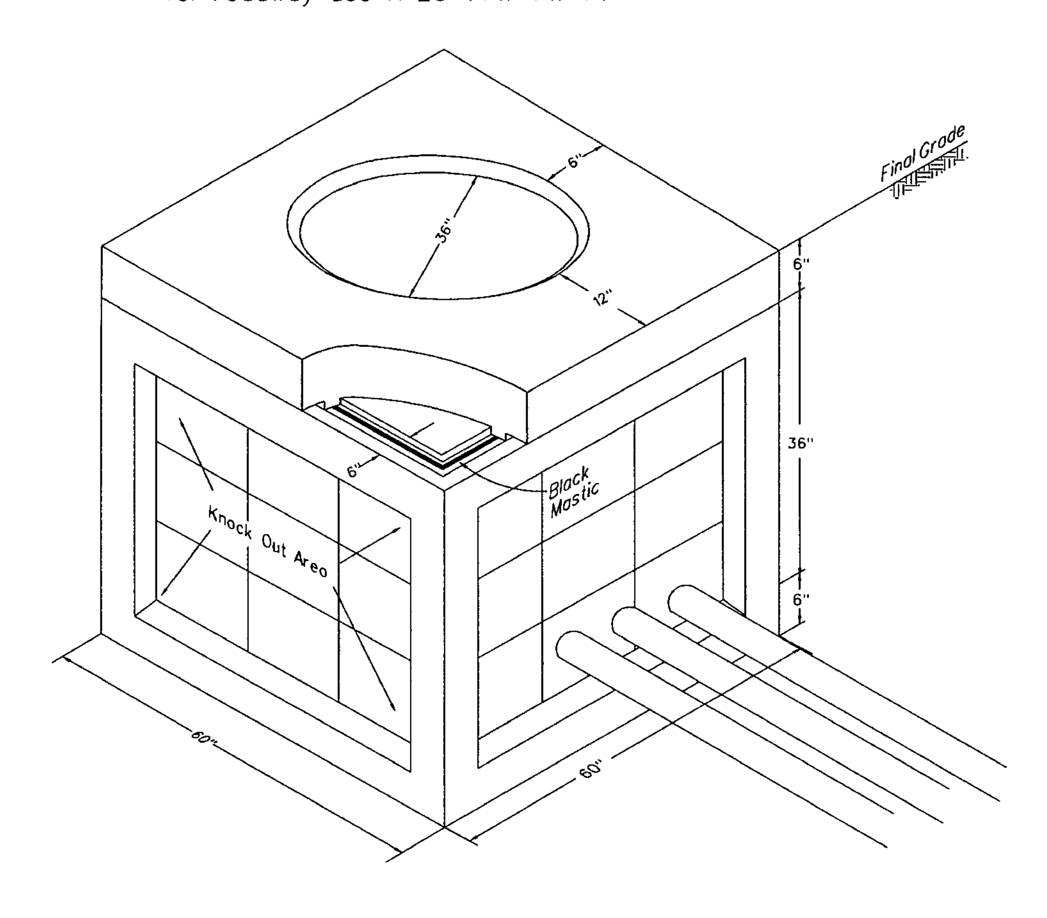
Installation Depth

Minimum - top of structure 1 ft. below ground level.
Maximum - top of structure 5 ft. below ground level.

Structural design must be approved by the Underground Standards Engineering Unit, Distribution Engineering Department before structure is acceptable for use on the underground distribution system. BGE designation *6.12.7.

1.16.1 Utility Company Electrical Splice Box for Roadway Use

Splice Box/Handhole
for roadway use H-20 (4'x 4'x 4')



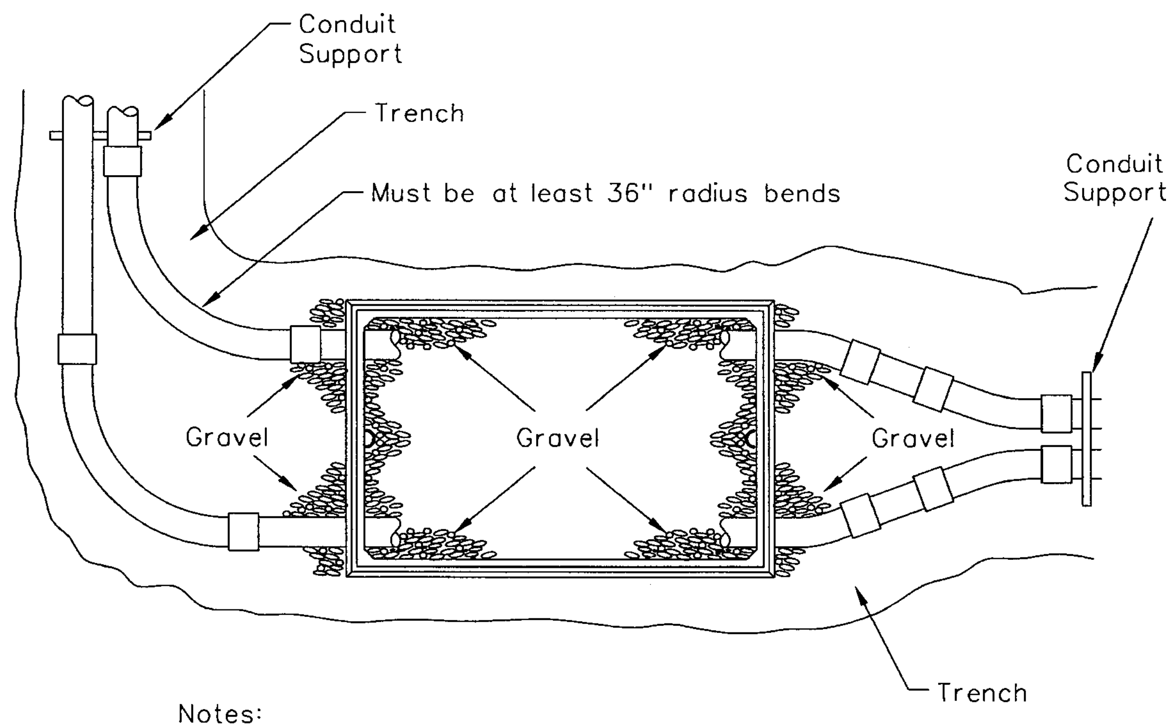
Concrete: 5000 psi @ 28 days
Steel Reinforcement
BGE can supply further specification as necessary.

Limit 6 Sets Secondary 500 kcmil Cable
Designated Enclosed Space (OSHA) - All Safety Procedures Must Be Met

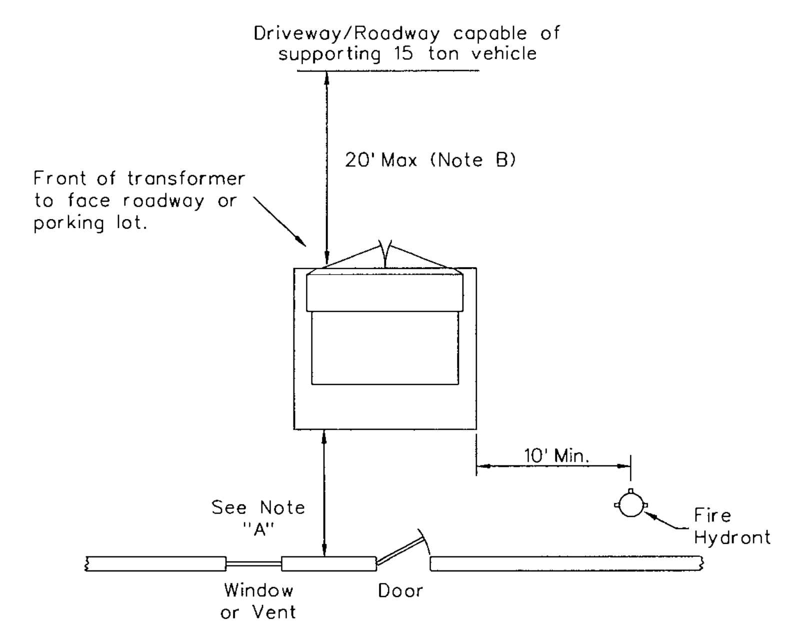
Internal Requirements:
- Sump - 12"dia x 4-1/2" deep
- Pulling Irons in floor
- Ground Rod -1/2" Cu-coated

BGE00590

1.16.2 Utility Company Electrical Splice Box for Nonroadway Use



1.16.3 Typical Utility Company Transformer Location Requirements



Notes:

A) 2 Ft. Min. To masonry fire resistant walls of buildings with no openings.

20 Ft. Min. To any flammable building wall. A min. diagonal dist. of 20 feet from top of transformer is required if placed beneath window, unless barrier wall is constructed according to BGE standards (can be supplied by BGE).

20 Ft. Min. On any opening in a building wall including: Doors, windows, ventilating exhaust, intake ducts or any fire escape.

B) 3 phase Transformer to be no further than 20 feet from a paved access road. (Single Phase can be 30' away) to allow vehicular access for future transformer/cable maintenance.

C) Traffic protection is required on all sides of transformer that are within 8' of a roadway or parking lot. (See Traffic Protection Standard)

D) The above are suggested minimum clearances between the transformer foundation and windows, doors, fire escapes, entrances and ventilating ducts. It shall be the customer's responsibility to see that applicable National Electrical Code, municipality and/or insurance regulations and requirements are met.

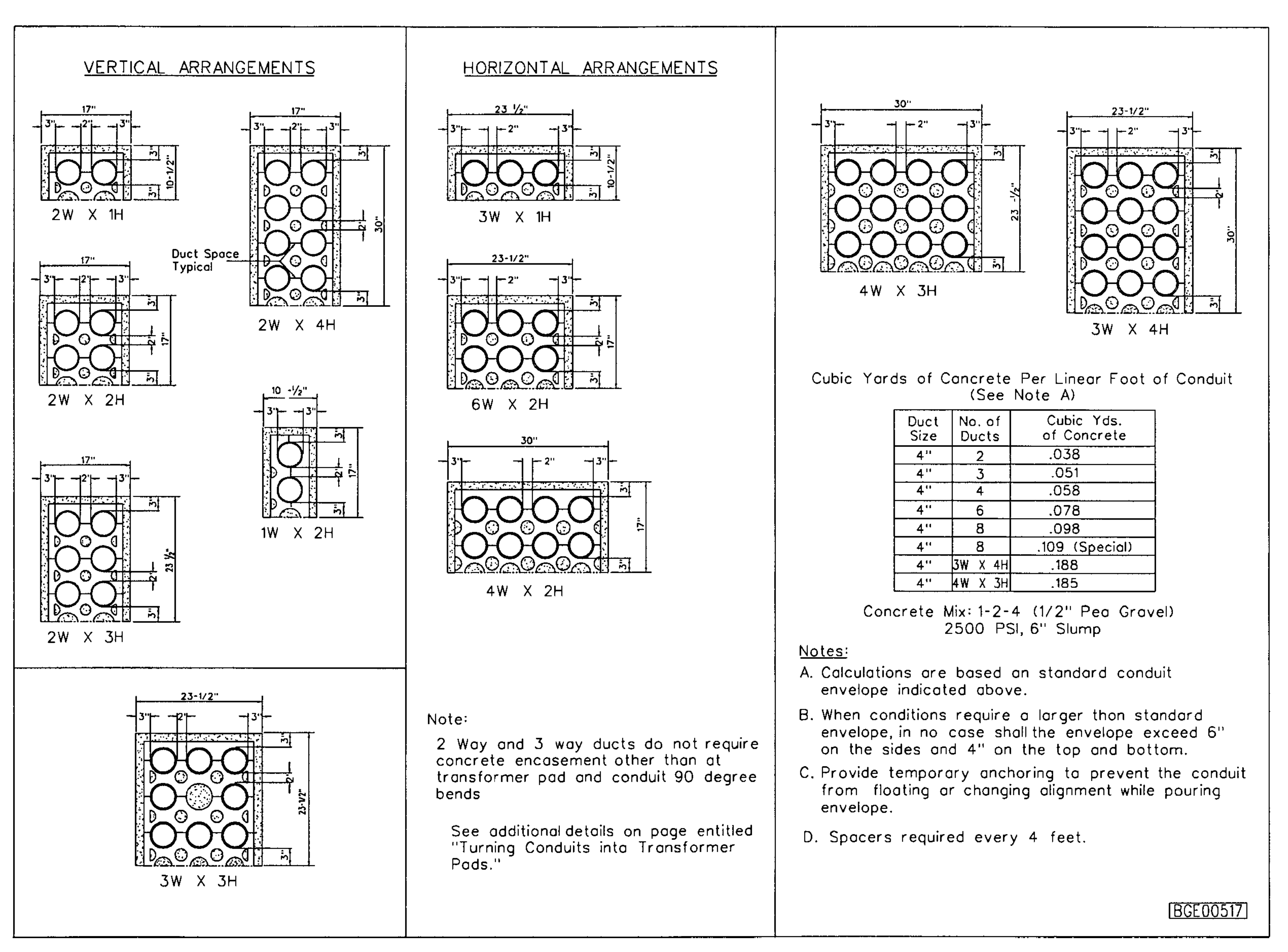
E) Tranformer location must have 5' horizontal clearance from any undergound facilities

BGE00547

Storm water run-off shall be directed away from transformers and other equipment. Transformers shall also be placed to prevent flooding of the building and/or electrical conduits. Transformers and conduits shall never be placed so that they drain toward a building, unless adequate drainage and run-off protection has been installed.

Transformer shall be placed on a level area with a minimum of eight feet of clear and level operating space in front of the transformer pad. The access road/paving area must be capable of supporting the weight of a 15-ton vehicle.

1.16.4 Duct Bank Configurations for Concrete Encasement of Conduits



Section

2

Substructures

Contents

2.0.0 Soil Types for Other Types of Underground Structures

Soil types and classifications are one of the determinant factors in the selection of the building's substructure, along with the weight of the structure to be imposed upon that foundation. In those cases where adequate bearing pressure is lacking and conventional cast-in-place foundations are not suitable, there are many other types of underground structures available to the design engineer.

2.0.1 History of Concrete

Concrete is an ancient material of construction, first used during the Roman Empire, which extended from about 20 B.C. to 200 A.D. The word *concrete* is derived from the Roman *concretus*, meaning to grow together. Although this early mixture was made with lime, cement, and a volcanic ash material called *pozzolana*, concrete today is a sophisticated material to which exotic constitutents can be added and, with computer-controlled batching, can produce a product capable of achieving 50,000 psi compressive strength.

The factors contributing to a successful batch of concrete are

- Precise measurement of water content;
- Type, size, and amount of cement and aggregate;
- Type, size, and location of reinforcement within the concrete pour to compensate for the lack of tensile strength basic in concrete;
- Proper curing procedures during normal hot or cold weather conditions.

2.0.2 General Properties of Concrete

With some exceptions, the two most widely used concrete mixtures are

- Normal-weight (stone) concrete with a dry weight of 145 psf (6.93 kPa);
- Lightweight concrete (LWC) with a weight of approximately 120 psf (5.74 kPa). Extra light concrete, with weights as low as 80 psf (3.82 kPa), an be achieved with the use of special aggregates.

2.0.3 Other Types of Concrete

- *Lightweight Insulating* Containing perlite, vermiculite, and expanded polystyrene, which is used as fill over metal roof decks, in partitions, and in panel walls.
- *Cellular* Contains air or gas bubbles suspended in mortar and either no coarse aggregates or very limited quantities are included in the mixture. Use where high insulating properties are required.
- *Shot-crete or Gunite* The method of placement characterizes this type of concrete, which is applied via pneumatic equipment. Typical uses are swimming pools, shells, or domes, where formwork would be complicated because of the shape of the structure.
- *Ferrocement* Basically a mortar mixture with large amounts of light-gauge wire reinforcing. Typical uses include bins, boat hulls, and other thin, complex shapes.

2.0.4 Portland Cement as a Major Component

Different types of portland cement are manufactured to meet specific purposes and job conditions.

- Type I is a general-purpose cement used in pavements, slabs, and miscellaneous concrete pads and structures.
- Type IA is used for normal concrete, to which an air-entraining admixture is added.
- Type II creates a moderate sulfur-resistant product that is used where concrete might be exposed to groundwater that contains sulfates.
- Type IIA is the same as Type II, but is suited for an air-entrainment admixture.

- Type III is known as *high early strength* and generates high strength in a week or less.
- Type IIIA is high early, to which an air-entrainment admixture is added.
- Type IV cement produces low heat of hydration and is often used in mass pours, such as dam construction or thick mat slabs.
- Type V is a high sulfate-resistant cement that finds application in concrete structures exposed to high sulfate-containing soils or groundwater.
- White Portland cement is generally available in Type I or Type III only and gains its white color from the selection of raw materials containing negligible amounts of iron and magnesium oxide. White cement is mainly used as a constituent in architectural concrete.

2.0.5 High Early Cement

High early cement does exactly what its name implies: it provides higher compressive strength at an earlier age. Although Type III or Type IIIA cement can produce high early strength, there are other ways to achieve the same end result:

- Add more cement to the mixture [600 lb (272 kg) to 1000 lb (454 kg)];
- Lower the water content (0.2 to 0.45) by weight;
- Raise the curing temperature after consultation with the design engineer;
- Introduce an admixture into the design mix;
- Introduce microsilica, also known as *silica fume*, to the design mix;
- Cure the cast-in-place concrete by autoclaving (steam curing);
- Provide insulation around the formed, cast-in-place concrete to retain heat of hydration.

2.0.6 How Cement Content Affects Shrinkage

When low slumps, created in conjunction with minimum water requirements, are used with correct placement procedures, the shrinkage of concrete will be held to a minimum. Conversely, high water content and high slumps will increase shrinkage. A study at the Massachusetts Institute of Technology, as reported by the Portland Cement Association, indicated that for every 1% increase in mixing water, shrinkage of concrete increased by 2%. This study produced the following chart, showing the correlation of water and cement content to shrinkage.

2.0.7 Effect of Cement/Water Content on Shrinkage

Cement Content Bags/cubic yard	Concrete composition							
	Cement	Water	Air	Aggregate	Water + air	Water cement ratio by weight	Slump (inches)	Shrinkage (av. 3 × 3 × 10* prism)
4.99	0.089	0.202	0.017	0.692	0.219	0.72	3.3	0.0330
5.99	0.107	0.207	0.016	0.670	0.223	0.62	3.6	0.330
6.98	0.124	0.210	0.014	0.652	0.224	0.54	3.8	0.0289
8.02	0.143	0.207	0.015	0.635	0.223	0.46	3.8	0.0300

2.0.8 Control Joints

Thermal shrinkage will occur and the object of control joints, sometimes referred to as construction joints is to avoid the *random cracking* that often comes about when a concrete slab dries and produces excess tensile stress. Control joint spacing depends upon the slab thickness, aggregate size, and water content, as reported by the Portland Cement Association in their articles "Concrete Floors on Concrete," second edition, 1983.

2.0.9 Maximum Spacing of Control Joints

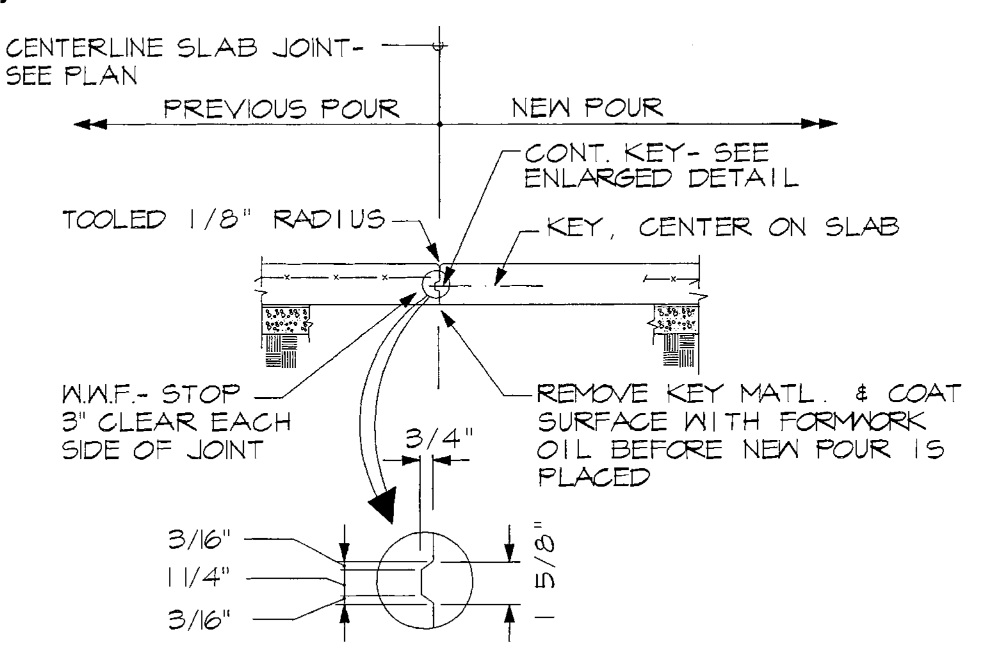
Slab Thickness	Slump of 4–6 inches (101.6 mm–152.4 mm) Max. size aggregate less than ¾ inches (19.05 mm)	Max. size aggregate larger than ¾ inches	Slump less than 4 inches (101.6 mm)
4" (101.6 mm)	8' (2.4 m)	10' (3.05 m)	12' (3.66 m)
5" (126.9 mm)	10' (3.05 m)	13' (3.96 m)	15' (4.57 m)
6" (152.4 mm)	12' (3.66 m)	15' (4.57 m)	18' (5.49 m)
7" (177.8 mm)	14' (4.27 m)	18' (5.49 m)	21' (6.4 m)
8" (203.1 mm)	16' (4.88 m)	20' (6.1 m)	24' (7.32 m)
9" (228.6 mm)	18' (5.49 m)	23' (7.01 m)	27' (8.23 m)
10" (253.9 mm)	20' (6.1 mm)	25' (7.62 m)	30' (9.14 m)

The term *control joint* is often used as being synonymous with *construction joint,* however, there is a difference between the two. A *control joint* is created to provide for movement in the slab and induce cracking at that point, whereas a *construction joint* is a bulkhead that ends that day's slab pour. When control joints are created by bulkheading off a slab pour, rather than saw-cutting after the slab has been poured, steel dowels are often inserted in the bulkhead to increase load transfer at this joint.

2.0.10 Dowel Spacing

Slab Depth in. (mm)	Diameter (bar number)	Total length in. (mm)	Spacing in. (mm) center to center
5" (126.9 mm)	#5	12 in. (304.8 mm)	12 in. (304.8 mm)
6" (152.4 mm)	#6	14 in. (355.6 mm)	12 in. (304.8 mm)
7" (177.8 mm)	#7	14 in. (355.6 mm)	12 in. (304.8 mm)
8" (203.1 mm)	#8	14 in. (355.6 mm)	12 in. (304.8 mm)
9" (228.6 mm)	#9	16 in. (406.4 mm)	12 in. (304.8 mm)
10" (253.9 mm)	#10	16 in. (406.4 mm)	12 in. (304.8 mm)

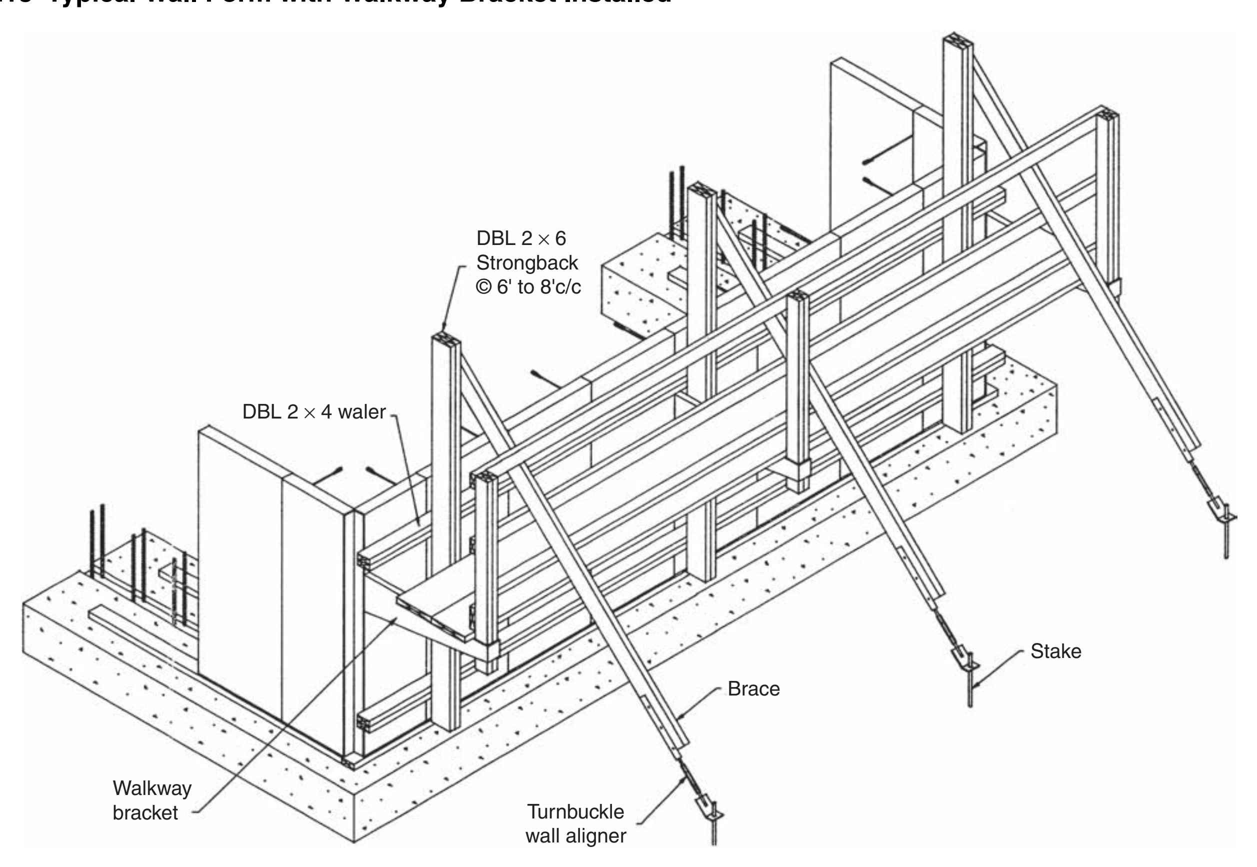
2.0.11 Keyed Construction Joint



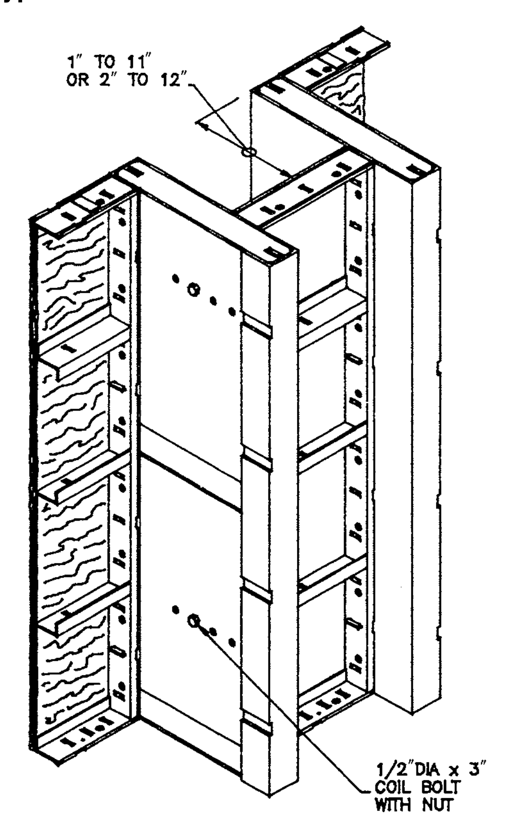
Key construction joint detail #2 (not to scale; detail T2-SKCJ2).
By permission from the McGraw-Hill Co., *Structural Detail Manual*, David R. Williams.

2.0.12 Typical Wall Form—One Side in Place

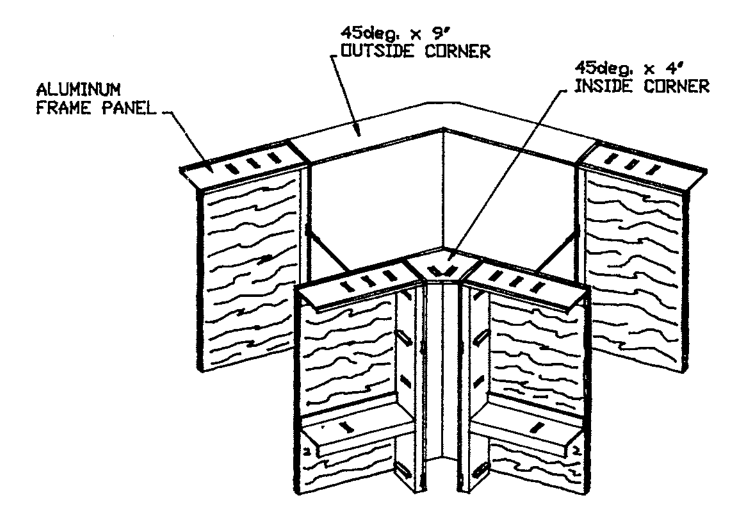
2.0.13 Typical Wall Form with Walkway Bracket Installed



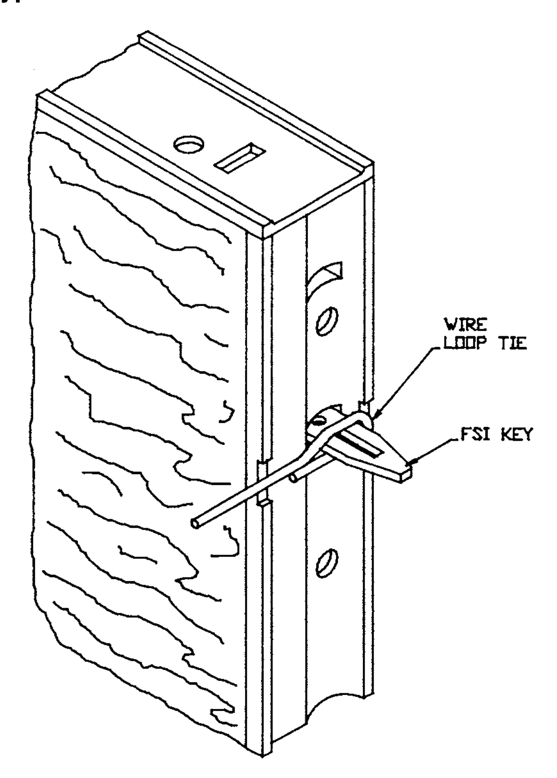
2.0.14 Typical Wall Pilaster Form



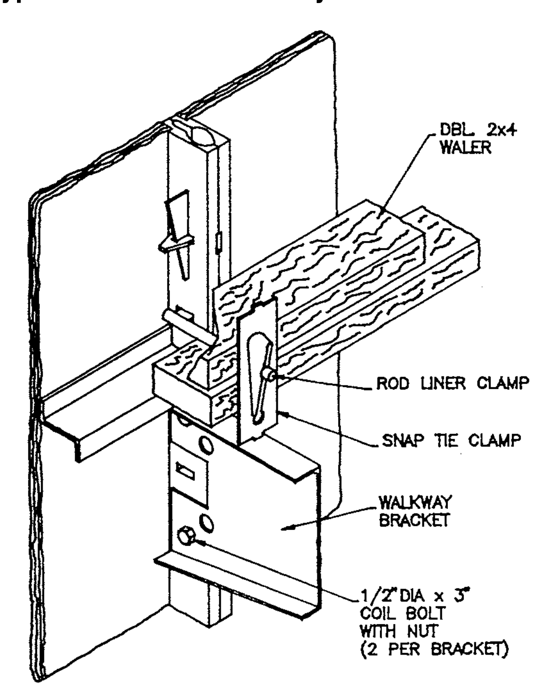
2.0.15 Typical 45° Corner



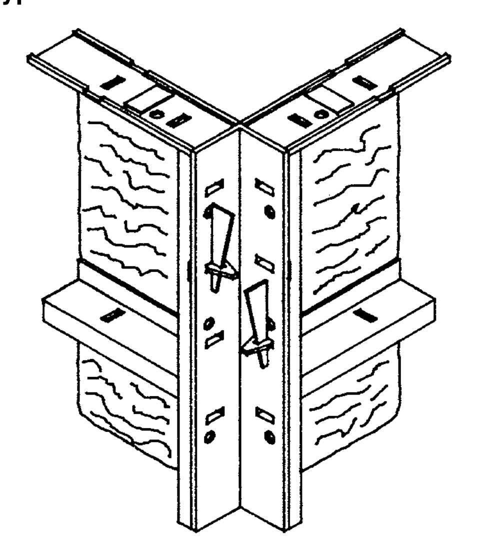
2.0.16 Typical Tie Connection



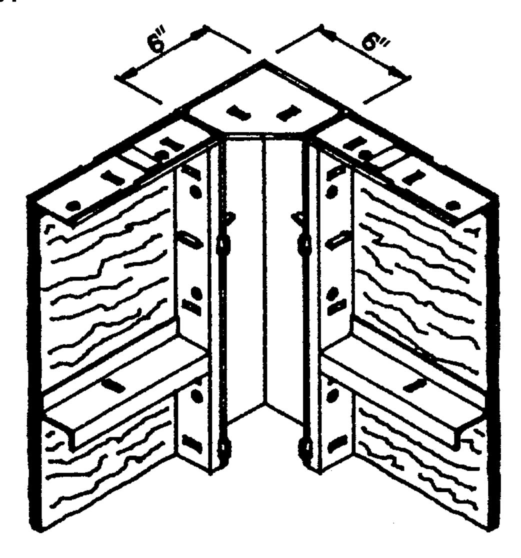
2.0.17 Typical Waler and Walkway Bracket



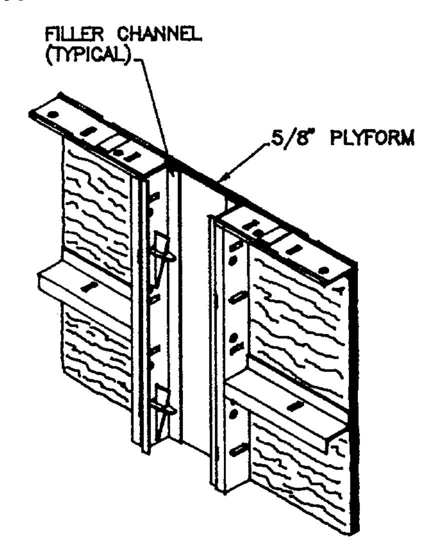
2.0.18 Typical 90° Outside Corner



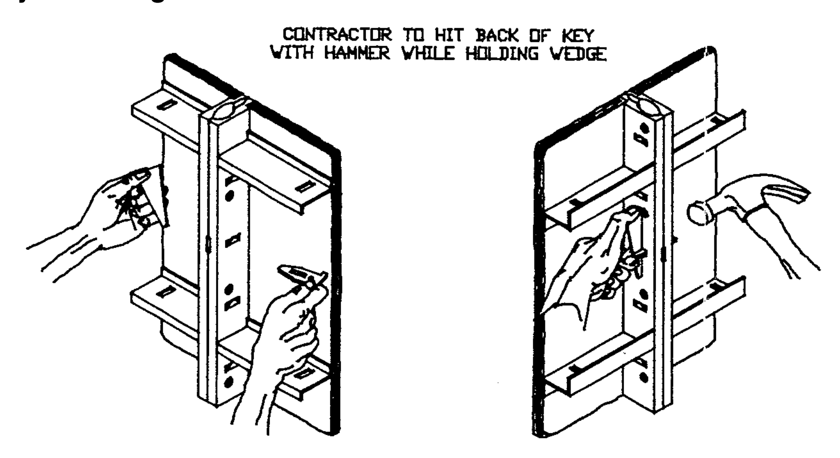
2.0.19 Typical 90° Inside Corner



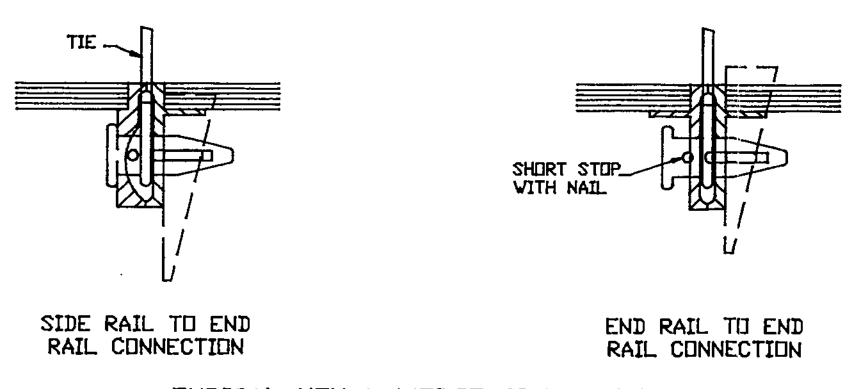
2.0.20 Typical Wood Filler



2.0.21 Key and Wedge Connections

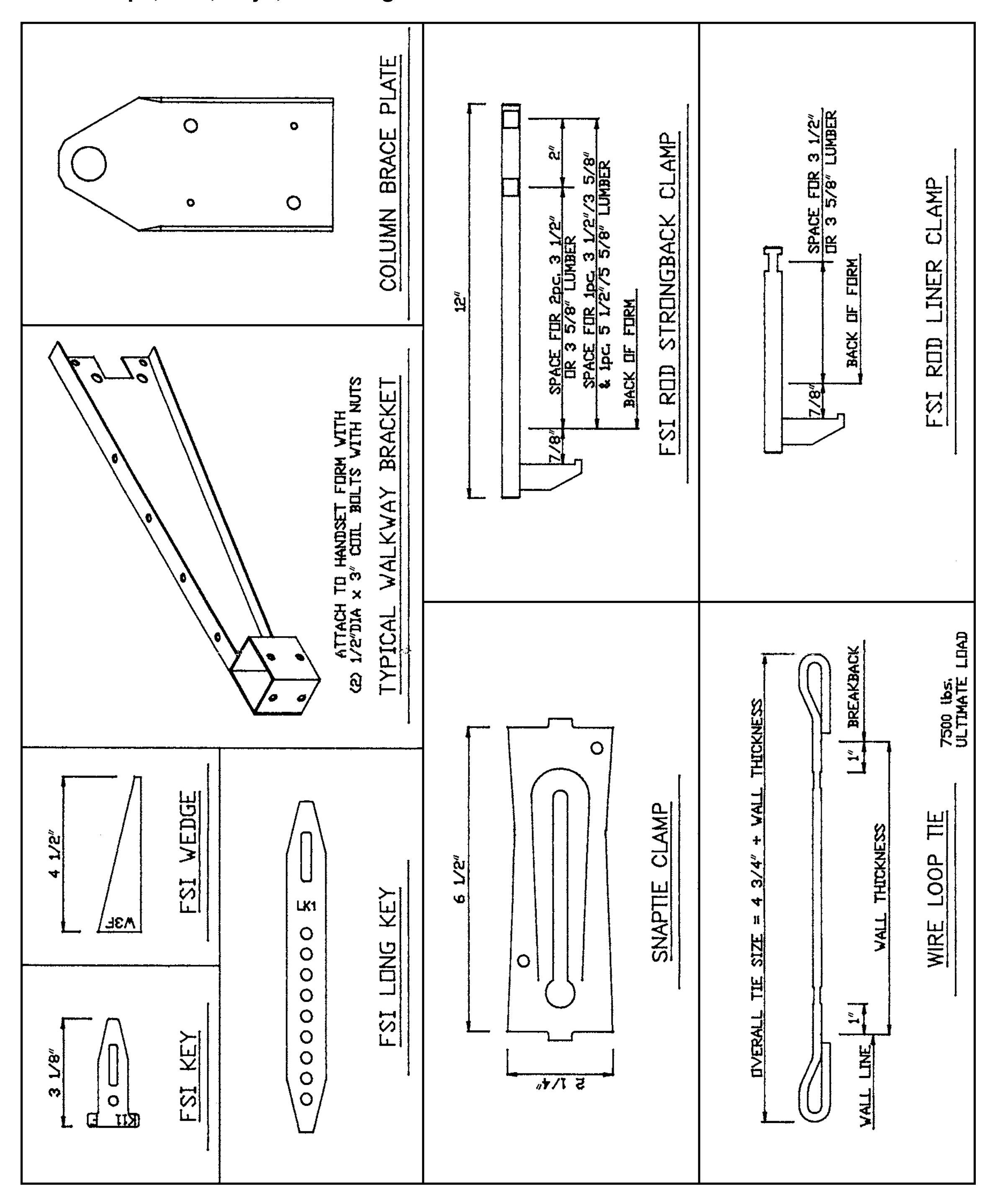


PROPER KEY & WEDGE INSTALLATION



TYPICAL KEY & WEDGE CONNECTION

2.0.22 Various Clamps, Ties, Keys, and Wedges



2.0.23 Admixtures

Although concrete is an extremely durable product, it faces deterioration from various sources: chemical attack, permeation by water and/or gases from external sources, cracking because of the chemical reaction (known as *heat of hydration*), corrosion of steel reinforcement, freeze/thaw cycles, and abrasion. Much of the deterioration caused by these internal and external factors can be drastically delayed by the addition of a chemical admixture to the ready-mix concrete.

Admixtures are chemicals developed to make it easier for a contractor to produce a high-quality concrete product. Some admixtures retard curing, some accelerate it; some create millions of microscopic bubbles in the mixture; others allow a substantial reduction in water content, but still permit the concrete to flow like thick pea soup.

- *Water-reducing admixtures* Improve strength, durability, workability of concrete. Available in normal range and high range.
- *High-range water-reducing admixture* Also known as superplasticizer, it allows up to 30% reduction in water content with no loss of ultimate strength, but it creates increased flowability. It is often required where reinforcing steel is placed very close together in intricate forms.
- *Accelerating admixtures* They accelerate the set time of concrete, thereby reducing the protection time in cold weather, allowing for earlier stripping of forms. Accelerating admixtures are available in both chloride- and nonchloride-containing forms. Nonchloride is required if concrete is to be in contact with metal and corrosion is to be avoided.
- *Retarder admixtures* Retards the setting time, a desirable quality during very hot weather.
- *Air-entraining admixtures* Creates millions of microscopic bubbles in the cured concrete, allowing for expansion of permeated water, which freezes and is allowed to expand into these tiny bubbles, thereby resisting hydraulic pressures caused by the formation of ice.
- *Fly ash* When added to the concrete mixture, it creates a more dense end product, making the concrete extremely impermeable to water, which affords more protection to steel reinforcement contained in the pour. The addition of fly ash can increase ultimate strength to as much as 6500 psi (44.8 MPa), in the process, making the concrete more resistant to abrasion.
- *Silica fume* Also known as microsilica, it consists of 90 to 97% silicon dioxide, containing various amounts of carbon that are spherical in size and average about 0.15 micron in size. These extremely fine particles disperse into the spaces around the cement grains and create a uniform dense microstructure that produces concrete with ultra-high compressive strengths, in the nature of 12,000 (82.73 MPa) to 17,000 psi (117.20 MPa).
- *Multifilament or fibrillated fibers* This material is not a chemical admixture per se, but several manufacturers of concrete chemical additives also sell containers of finely chopped synthetic fibers, generally polypropylene, which, when added to the ready-mix concrete, serve as secondary reinforcement and prevent cracks.

2.0.24 Chloride Content in Mixing Water

Excessive chloride ions in mixing water can contribute to accelerated reinforcing-steel corrosion and should be a concern when evaluating a mix design. Maximum water-soluble chloride ions, in various forms of concrete (as a percentage), should not exceed the following:

- Prestressed concrete 0.06%
- Reinforced concrete exposed to chloride in service (e.g., garbage slab) 0.15%
- Reinforced concrete that will be dry and/or protected from moisture infiltration 1.00%
- Other reinforced concrete 0.30%

2.0.25 Guidelines—Mixing Small Batches of Concrete by Weight

Max. size aggregate	Cement (lb/kg)	Wet-fine aggregate (lb/kg)	Wet-coarse aggregate (lb/kg)	Water (lb/kg)
⅜" (9.52 mm)	29 lb (13.15 kg)	59 lb (26.76 kg)	46 lb (20.87 kg)	11 lb (4.99 kg)
½" (12.6 mm)	27 lb (12.25 kg)	53 lb (24.04 kg)	55 lb (24.95 kg)	11 lb (4.99 kg)
¾" (19.05 mm)	25 lb (11.34 kg)	47 lb (21.32 kg)	65 lb (29.66 kg)	10 lb (4.54 kg)
1" (25.39 mm)	24 lb (10.89 kg)	45 lb (20.41 kg)	70 lb (31.75 kg)	10 lb (4.54 kg)
1½" (37.99 mm)	23 lb (10.43 kg)	43 lb (19.50 kg)	75 lb (34.02 kg)	9 lb (4.08 kg)

2.0.26 Guidelines—Mixing Small Batches of Concrete by Volume

Max. size aggregate	Cement	Wet-fine aggregate	Wet-coarse aggregate	Water
⅜" (9.52 mm)	1	2½	1½	½
½" (12.6 mm)	1	2½	2	½
¾" (19.05 mm)	1	2½	2½	½
1" (25.39 mm)	1	2½	2¾	½
1½" (37.99 mm)	1	2½	3	½

2.0.27 Recommended Slumps

The Portland Cement Association recommends the following slumps:

Component	Max. slump (inches)	Min. slump (inches)
Footings (reinforced or not)	3	1
Foundation walls	3	1
Substructure walls	3	1
Caissons	3	1
Beams and reinforced walls	4	1
Building columns	4	1
Pavements and slabs	3	1
Mass concrete	2	1

2.0.28 Slump Test

Slump, as it relates to concrete, is a measure of consistency equal to the decrease in height, measured to the nearest ¼ inch (6 mm) of the molded mass immediately after it has been removed from this molded mass created by the "slump cone."

The mold is in the form of a frustum (part of a solid cone intersected by the use of parallel lines) 12 inches (2.5 cm) high, with a base diameter of 8 inches (2 cm) and a top diameter of 4 inches (1 cm).

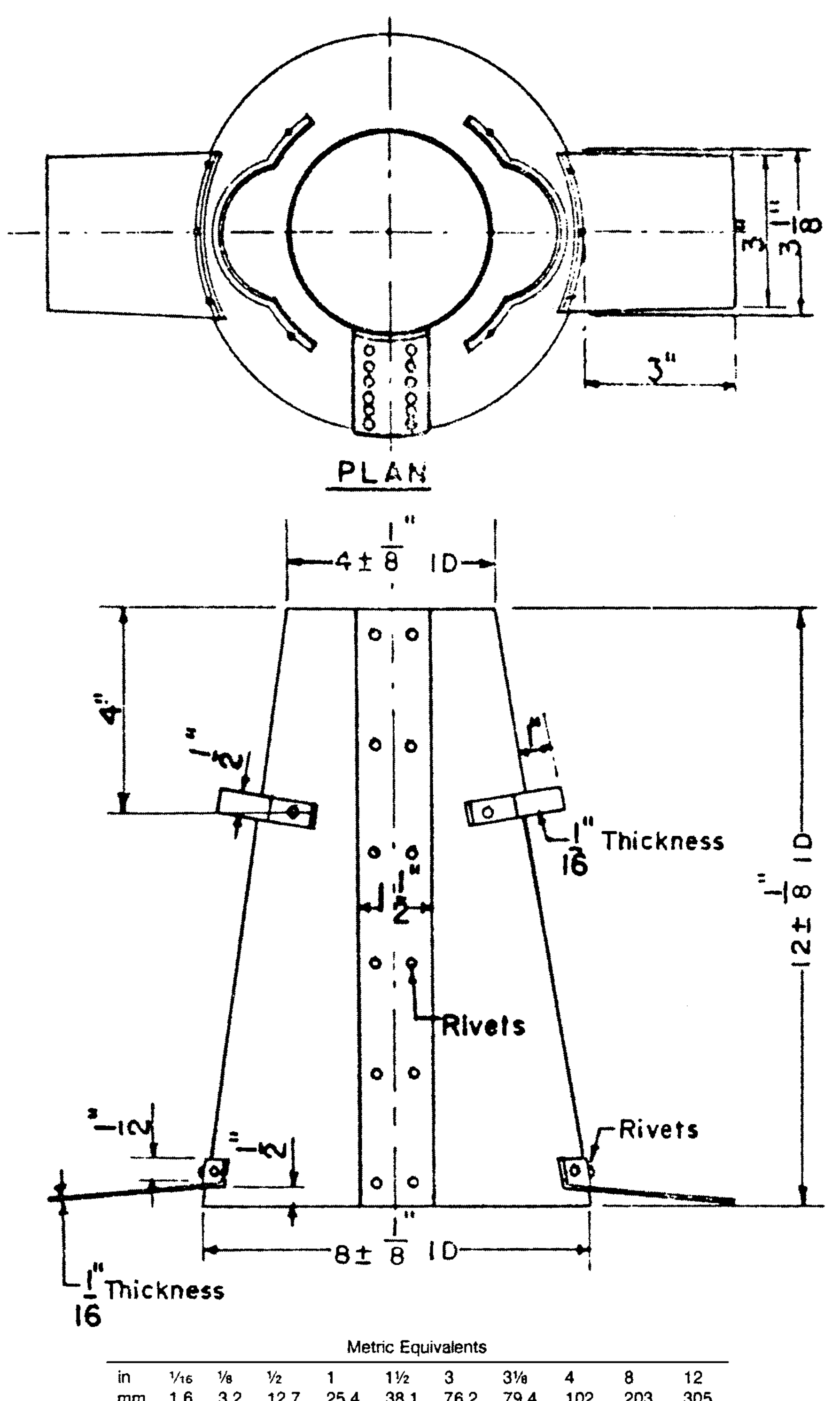
This mold (slump cone) is filled with freshly mixed concrete in three layers, each being rodded with a ⅝-inch (15.9 mm) bullet-shaped rod 25 times. When the mold has been filled, the top is struck off and the mold is lifted. The amount by which the mass settles after mold removal is referred to as *slump*. A small slump is an indication of a very stiff mix, and a very large slump is indicative of a very wet consistency.

Recommended slumps are:

Type of construction	Maximum slump (inches)	Minimum slump (inches)
Reinforced walls/footings	3 (76.2 mm)	1 (25.4 mm)
Caissons, substructure walls	3	1
Beams, reinforced walls	4 (102 mm)	1
Building columns	4	1
Pavements, slabs	3	1
Mass concrete	2 (50.8 mm)	1

Rule of thumb: To raise the slump 1 inch (25.4 mm), add 10 pounds of water for each cubic yard of concrete. (One gallon of water equals 8.33 pounds.)

2.0.29 Slump Cone



Metric Equivalents

in	1/16	1/8	1/2	1	1 1/2	3	3 1/8	4	8	12
mm	1.6	3.2	12.7	25.4	38.1	76.2	79.4	102	203	305

2.0.30 Curing of Concrete—Curing Procedures

To attain design strength, curing is a crucial part of the cast-in-place concrete process in order that the proper amount of moisture content and ambient temperature be maintained immediately following the placement of the concrete. The optimum curing cycle will take into account the prevention or replenishment of moisture content from the concrete and the maintenance of a favorable temperature for a specific period of time. During winter months, temporary protection and heat is required in conjunction with the curing process, and during summer months, moisture replenishment becomes an integral part of the curing process.

1. Apply a membrane-curing compound—either by spraying or rolling on the surface immediately after the troweling process on slabs has ceased, or on walls, columns, beams, after the forms have been removed.
2. Curing by water in other than cold-weather conditions is acceptable, as long as it is continuous.
3. Waterproof paper, applied directly over the concrete surface after it has received a spray of water, is often effective.
4. Damp burlap, free of foreign substances that could leach out and stain the concrete, is also a proven curing procedure, as long as the burlap is kept moist.
5. Polyethylene sheets can be used as a blanket in much the same manner as waterproof paper, as long as its edges are lapped and sealed properly.
6. Damp sand or straw is also used on occasion, when nothing else is available. These materials must also be sprayed from time to time to maintain the moisture content.

The length of curing depends upon a number of factors, including the type of cement used and ambient temperatures. The following can be used as a guideline to determine the length of curing time.

2.0.31 Curing Times

At 50°F (10°C)

Percentage design strength required	Type cement used in mix		
	I	II	III
50%	6	9	3
65%	11	14	5
85%	21	28	16
95%	29	35	26

At 70°F (21°C) Days

Percentage design strength required	Type cement used in mix		
	I	II	III
50%	6	9	3
65%	11	14	5
85%	21	28	16
95%	29	35	26

2.0.32 Concrete Reinforcing Bar Size/Weight Chart

BAR SIZE DESIGNATION	WEIGHT POUNDS PER FOOT	NOMINAL DIMENSIONS–ROUND SECTIONS		
		DIAMETER INCHES	CROSS-SECTIONAL AREA-SQ INCHES	PERIMETER INCHES
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430
#14	7.650	1.693	2.25	5.320
#18	13.600	2.257	4.00	7.090

2.0.33 ASTM Standard Including Soft Metric

Soft metric size	Nom diam mm	Area mm^2	Weight factors		Imperial size	Nom diam inches	Area in^2	Weight factors	
			kg/m	kg/ft				lb/ft	lb/m
10	9.5	71	.560	.171	3	.375	.11	.376	1.234
13	12.7	129	.994	.303	4	.500	.20	.668	2.192
16	15.9	199	1.552	.473	5	.625	.31	1.043	3.422
19	19.1	284	2.235	.681	6	.750	.44	1.502	4.928
22	22.2	387	3.042	.927	7	.875	.60	2.044	6.706
25	25.4	510	3.973	1.211	8	1.000	.79	2.670	8.760
29	28.7	645	5.060	1.542	9	1.128	1.00	3.400	11.155
32	32.3	819	6.404	1.952	10	1.270	1.27	4.303	14.117
36	35.8	1006	7.907	2.410	11	1.410	1.56	5.313	17.431
43	43.0	1452	11.384	3.470	14	1.693	2.25	7.650	25.098
57	57.3	2581	20.239	6.169	18	2.257	4.00	13.600	44.619

Comparison of Steel Grades

Soft metric			Imperial		
Grade	mPa	psi	Grade	mPa	psi
300	300	43,511	40	257.79	40,000
420	420	60,716	60	413.69	60,000
520	520	75,420	75	517.11	75,000

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2.0.34 Welded Wire Fabric (WWF)

Wire size number		Nominal diameter, in.	Nominal weight, lb/ft	Area per width (in.²/ft) for various spacings (in)						
Plain	Deformed			2	3	4	6	8	12	16
W45	D45	0.757	1.53	2.70	1.80	1.35	0.90	0.68	0.45	0.34
W31	D31	0.628	1.05	1.86	1.24	0.93	0.62	0.47	0.31	0.23
W20	D20	0.505	0.680	1.2	0.80	0.60	0.40	0.30	0.20	0.15
W18	D18	0.479	0.612	1.1	0.72	0.54	0.36	0.27	0.18	0.14
W16	D16	0.451	0.544	0.96	0.64	0.48	0.32	0.24	0.16	0.12
W14	D14	0.422	0.476	0.84	0.56	0.42	0.28	0.21	0.14	0.11
W12	D12	0.391	0.408	0.72	0.48	0.36	0.24	0.18	0.12	0.09
W11	D11	0.374	0.374	0.66	0.44	0.33	0.22	0.17	0.11	0.08
W10.5		0.366	0.357	0.63	0.42	0.32	0.21	0.16	0.11	0.08
W10	D10	0.357	0.340	0.60	0.40	0.30	0.20	0.15	0.10	0.08
W9.5		0.348	0.323	0.57	0.38	0.29	0.19	0.14	0.095	0.07
W9	D9	0.338	0.306	0.54	0.36	0.27	0.18	0.14	0.090	0.07
W8.5		0.329	0.289	0.51	0.34	0.26	0.17	0.13	0.085	0.06
W8	D8	0.319	0.272	0.48	0.32	0.24	0.16	0.12	0.080	0.06
W7.5		0.309	0.255	0.45	0.30	0.23	0.15	0.11	0.075	0.06
W7	D7	0.299	0.238	0.42	0.28	0.21	0.14	0.11	0.070	0.05
W6.5		0.288	0.221	0.39	0.26	0.20	0.13	0.097	0.065	0.05
W6	D6	0.276	0.204	0.36	0.24	0.18	0.12	0.090	0.060	0.05
W5.5		0.265	0.187	0.33	0.22	0.17	0.11	0.082	0.055	0.04
W5	D5	0.252	0.170	0.30	0.20	0.15	0.10	0.075	0.050	0.04
W4.5		0.239	0.153	0.27	0.18	0.14	0.090	0.067	0.045	0.03
W4	D4	0.226	0.136	0.24	0.16	0.12	0.080	0.060	0.040	0.03
W3.5		0.211	0.119	0.21	0.14	0.11	0.070	0.052	0.035	0.03
W3		0.195	0.102	0.18	0.12	0.090	0.060	0.045	0.030	0.02
W2.9		0.192	0.099	0.17	0.12	0.087	0.058	0.043	0.029	0.02
W2.5		0.178	0.085	0.15	0.10	0.075	0.050	0.037	0.025	0.02
W2.1		0.162	0.070	0.13	0.84	0.063	0.042	0.031	0.021	0.02
W2		0.160	0.068	0.12	0.080	0.060	0.040	0.030	0.020	0.02
W1.5		0.138	0.051	0.090	0.060	0.045	0.030	0.022	0.015	0.01
W1.4		0.134	0.048	0.084	0.056	0.042	0.028	0.021	0.014	0.01

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2.0.35 Types of Welded Wire Fabric

Style designation (W = Plain, D = Deformed)	Steel area (in²/ft)		Approximate weight (lb per 100 sq ft)
	Longitudinal	Transverse	
4 x 4-W1.4 x W1.4	0.042	0.042	31
4 x 4-W2.0 x W2.0	0.060	0.060	43
4 x 4-W2.9 x W2.9	0.087	0.087	62
4 x 4-W/D4 x W/D4	0.120	0.120	86
6 x 6-W1.4 x W1.4	0.028	0.028	21
6 x 6-W2.0 x W2.0	0.040	0.040	29
6 x 6-W2.9 x W2.9	0.058	0.058	42
6 x 6-W/D4 x W/D4	0.080	0.080	58
6 x 6-W/D4.7 x W/D4.7	0.094	0.094	68
6 x 6-W/D7.4 x W/D7.4	0.148	0.148	107
6 x 6-W/D7.5 x W/D7.5	0.150	0.150	109
6 x 6-W/D7.8 x W/D7.8	0.156	0.156	113
6 x 6-W/D8 x W/D8	0.160	0.160	116
6 x 6-W/D8.1 x W/D8.1	0.162	0.162	118
6 x 6-W/D8.3 x W/D8.3	0.166	0.166	120
12 x 12-W/D8.3 x W/D8.3	0.083	0.083	63
12 x 12-W/D8.8 x W/D8.8	0.088	0.088	67
12 x 12-W/D9.1 x W/D9.1	0.091	0.091	69
12 x 12-W/D9.4 x W/D9.4	0.094	0.094	71
12 x 12-W/D16 x W/D16	0.160	0.160	121
12 x 12-W/D16.6 x W/D16.6	0.166	0.166	126

*Many styles may be obtained in rolls.

2.1.0 Piles—Types

Piles can be classified into three basic types with respect to load transmission and function:

- End bearing piles—those piles that transfer their imposed load onto a firm subsurface stratum.
- Friction piles—those piles that carry their load by the adhesion friction of the soil along the entire surface area of the pile.
- A combination of friction and end bearing. A cast-in-place concrete pile placed via a steel form where a large bulb has been forced into the end bearing bottom. This pile is also known as a Franki pile for its originating company.

Pile foundations can be prepared using timber, steel, concrete, or fiberglass pilings. Each type has a unique characteristic.

2.1.0.1 Advantages and Disadvantages of Different Types of Piles

Wood piles

+ The piles are easy to handle.
+ Relatively inexpensive where timber is plentiful.
+ Sections can be joined together and excess length easily removed.
– The piles will rot above the groundwater level. Have a limited bearing.
– Can easily be damaged during driving by stones and boulders.
– The piles are difficult to splice and are attacked by marine borers in salt water.

Prefabricated concrete piles (reinforced) and prestressed concrete piles affected by the ground-water conditions.

+ Do not corrode or rot.
+ Are easy to splice. Relatively inexpensive.
+ The quality of the concrete can be checked before driving.
+ Stable in squeezing ground, for example, soft clays, silts and peats pile material can be inspected before piling.
+ Can be re driven if affected by ground heave. Construction procedure unaffected by groundwater.
+ Can be driven in long lengths. Can be carried above ground level, for example, through water for marine structures.
+ Can increase the relative density of a granular founding stratum.

– Relatively difficult to cut.
– Displacement, heave, and disturbance of the soil during driving.
– Can be damaged during driving. Replacement piles may be required.
– Sometimes problems with noise and vibration.
– Cannot be driven with very large diameters or in condition of limited headroom.

Driven and cast-in-place concrete piles

Permanently cased (casing left in the ground)

Temporarily cased or uncased (casing retrieved)

+ Can be inspected before casting can easily be cut or extended to the desired length.
+ Relatively inexpensive.
+ Low noise level.
+ The piles can be cast before excavation.
+ Pile lengths are readily adjustable.
+ An enlarged base can be formed which can increase the relative density of a granular founding stratum leading to much higher end bearing capacity.
+ Reinforcement is not determined by the effects of handling or driving stresses.
+ Can be driven with closed end so excluding the effects of GW.

– Heave of neighboring ground surface, which could lead to re consolidation and the development of negative skin friction forces on piles.
– Displacement of nearby retaining walls. Lifting of previously driven piles, where the penetration at the toe have been sufficient to resist upward movements.
– Tensile damage to unreinforced piles or piles consisting of green concrete, where forces at the toe have been sufficient to resist upward movements.
– Damage piles consisting of uncased or thinly cased green concrete due to the lateral forces set up in the soil, for example, necking or waisting. Concrete cannot be inspected after completion. Concrete may be weakened if artesian flow pipes up shaft of piles when tube is withdrawn.
– Light steel section or precast concrete shells may be damaged or distorted by hard driving.
– Limitation in length owing to lifting forces required to withdraw casing, nose vibration and ground displacement may be a nuisance or may damage adjacent structures.
– Cannot be driven where headroom is limited.
– Relatively expensive.

Bored and cast-in-place (non-displacement piles)

+ Length can be readily varied to suit varying ground conditions.
+ Soil removed in boring can be inspected and if necessary sampled or in-situ test made.
+ Can be installed in very large diameters.
+ End enlargement up to two or three diameters is possible in clays.
+ Material of piles is not dependent on handling or driving conditions.
+ Can be installed in very long lengths.
+ Can be installed without appreciable noise or vibrations.
+ Can be installed in conditions of very low headroom.
+ No risk of ground heave.
– Susceptible to “waisting” or “necking” in squeezing ground.
– Concrete is not placed under ideal conditions and cannot be subsequently inspected.
– Water under artesian pressure may pipe up pile shaft washing out cement.
– Enlarged ends cannot be formed in cohesionless materials without special techniques.
– Cannot be readily extended above ground level especially in river and marine structures.
– Boring methods may loosen sandy or gravely soils requiring base grouting to achieve economical base resistance.
– Sinking piles may cause loss of ground I cohesion-less leading to settlement of adjacent structures.

Steel piles (Rolled steel section)

+ The piles are easy to handle and can easily be cut to desired length.
+ Can be driven through dense layers. The lateral displacement of the soil during driving is low (steel section H or I section piles) can be relatively easily spliced or bolted.
+ Can be driven hard and in very long lengths.
+ Can carry heavy loads.
+ Can be successfully anchored in sloping rock.
+ Small displacement piles particularly useful if ground displacements and disturbance critical.
– The piles will corrode.
– Will deviate relatively easily during driving.
– Are relatively expensive.

2.1.1 Timber Piles

Treated timbers are used in marine applications where they will remain submerged below water level to preserve their life. Timber piles are also used by homebuilders in areas where subsurface water is close to the surface and the underlying soils will not support a conventional foundation.

2.1.2 Specifications for Timber Piles

Section 4165. Timber Piles.

4165.01 DESCRIPTION.
Timber piles shall be round sections of the trunks of trees trimmed, peeled, and with or without preservative treatment. They shall meet the requirements for the class of piles specified in the contract documents.

Inspection arrangements shall be in accordance with Materials I.M. 462. The cost of inspection shall be included in the unit price bid for the material specified.

4165.02 CLASSIFICATION.
Piles shall be classified as follows, according to the use for which they are intended:

A. Untreated Timber Piles.
Untreated timber piles may be used for falsework or temporary construction.

B. Treated Timber Foundation Piles.
Treated timber foundation piles will be used for permanent foundations and for permanent wood substructures above groundwater level, unless treated timber trestle piles are specified in the contract documents.

C. Treated Timber Trestle Piles.
Treated timber trestle piles shall be used for permanent wood trestle and may be specified for piers and abutments of substructures, where the more restrictive straightness requirements of this class are desirable.

4165.03 UNTREATED TIMBER PILES.
Timber piles to be used where preservative treatment is not required may be White Oak, Burr Oak, Cypress, Tamarack, Douglas Fir, Southern Pine, or other wood which will satisfactorily withstand driving. They shall meet the following requirements:

A. General Quality.
Piles shall be cut above the ground swell from live, sound, solid trees and shall have a gradual taper from point of butt measurement to tip. They shall be free from ring shakes, decay or rot, unsound knots, soft red heart, splits, and other defects which will impair their strength or durability. Cypress piles showing "peck" more than a single spot equal to 3% of the area of the end will not be accepted. Piles shall be free from excessive checks at the tip which would cause splits in driving.

B. Knots.
Piles shall have no unsound knots. Sound knots will be permitted, provided they are not in clusters, and provided the diameter of any single knot is not larger than 4 inches (100 mm) or 30% the diameter of the pile at the point where it occurs, whichever is smaller. The sum of diameters of all knots in any 1 foot (0.3 m) length of pile shall not exceed 2 times the diameter of the allowable knot. Diameters of knots shall be measured in a plane perpendicular to the long axis of the pile.

C. Rate of Growth.
When measured at the butt, over the outer 3 inches (75 mm) of a radial line from the pith, piles shall show not less than the number of annual rings and percentage of summerwood specified below for the respective species:

SUMMERWOOD		
Species	Rings per Inch (25 mm)	Minimum
Douglas Fir Douglas Fir	More than 5 5 or less	30%
Southern Pine Southern Pine	More than 5 3 to 5	30%

2.1.2 Specifications for Timber Piles (Continued)

When the number of annual rings varies along different radii, the average of two or more measurements along representative radii shall be used.

D. Holes.

Holes shall be permitted if less than 1/2 inch (13 mm) in average diameter, if they do not penetrate more than 20% the diameter at the point where they occur, and if the sum of the average diameters of all holes in any square foot (0.1 m^2) of pile surface does not exceed 1 1/2 inches (40 mm).

E. Twist of Grain.

Piles shall be free of twist in grain exceeding 50% the average circumference in a 20 foot (6 m) length.

F. Length.

Piles shall be furnished in the length specified in the contract documents or as directed by the Engineer. A variation of 6 inches (150 mm) in length will be permitted, but the average length for piles of any one lot shall be at least equal to the specified length.

G. Straightness.

Piles shall be free from sweep in two planes (double sweep). They shall be free of short crooks. In measuring for short crooks in any 5 foot (1.5 m) section, the distance from the center of the pile at the point of greatest deviation to a line stretched from the center of the pile above the bend to the center of the pile below the bend shall not exceed 4% of the length of the bend, or a maximum of 2 1/2 inches (65 mm). In sweep in one direction and in one plane, the center of the pile shall not deviate from a straight line connecting the center of butt with the center of the tip by more than 1.0% of the length of the pile, or 4 inches (100 mm), whichever is greater, with a maximum deviation of 6 inches (150 m) for lengths over 50 feet (15 m). Piles with sweep in two directions in the same plane (reverse sweep) may be accepted, provided the reversal is within the middle half of the length, and provided the deviation of the center of the pile from a straight line connecting the center of the butt with the center of the tip does not exceed 2 inches (50 mm). Within 25% of the length of the pile, but not less than 10 feet (3 m) nearest the tip, the center of the pile shall not deviate more than 1 inch (25 mm) from a line drawn from the center of the pile above this length to the center of the tip.

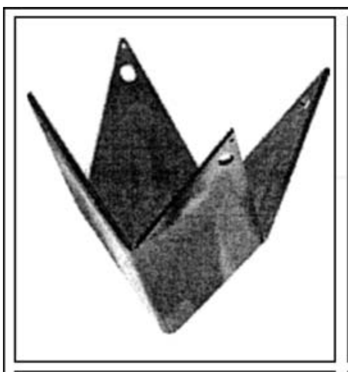
H. Dimensions.

At least 95% of the pieces of one length in any one shipment shall conform to the following dimensions for the species of wood specified. The remaining 5% of the pieces may be deficient in diameter at tip or 3 feet (1 m) from butt by not more than 1/2 inch (13 mm).

	Min. Diameter 3 Feet (1 m) From Butt		
Length feet (m)	**Fir & Pine** inches (mm)	**Other Species** inches (mm)	**Min. Tip Diameter** inches (mm)
20 and shorter (6.0)	10* (250*)	10* (250*)	8 (200)
25 to 30 (7.5 to 9.5)	11 (275)	11 (275)	8 (200)
35 (10.5)	12 (300)	13 (325)	8 (200)
40 (12.0)	12 (300)	13 (325)	7 (175)
40 to 60 (13.5 to 18.0)	13 (325)	14 (350)	7 (175)
over 60 (18.0)	13 (325)	14 (350)	6 (150)
*Measured at the butt.			

The diameter of the piles, at the butt, shall not exceed 20 inches (500 mm).

2.1.2.1 Boot and Point Tips for Timber Piles



~ VS 600 Series ~
Arrowhead Type Timber Pile Points

This fully welded tip attaches easily to the timber pile with just four nails. It comes in three sizes: 5" to 10", 8" to 12", and 11" to 15".

- Made to Corps of Engr. Specs
- Usually made to order
- Manufactured Regionally



Boot Type Timber Pile Points

For timber piles, this tough carbon steel boot is easy to attach. Just drive six nails into the straps. It is available in 8 inch inside diameter.

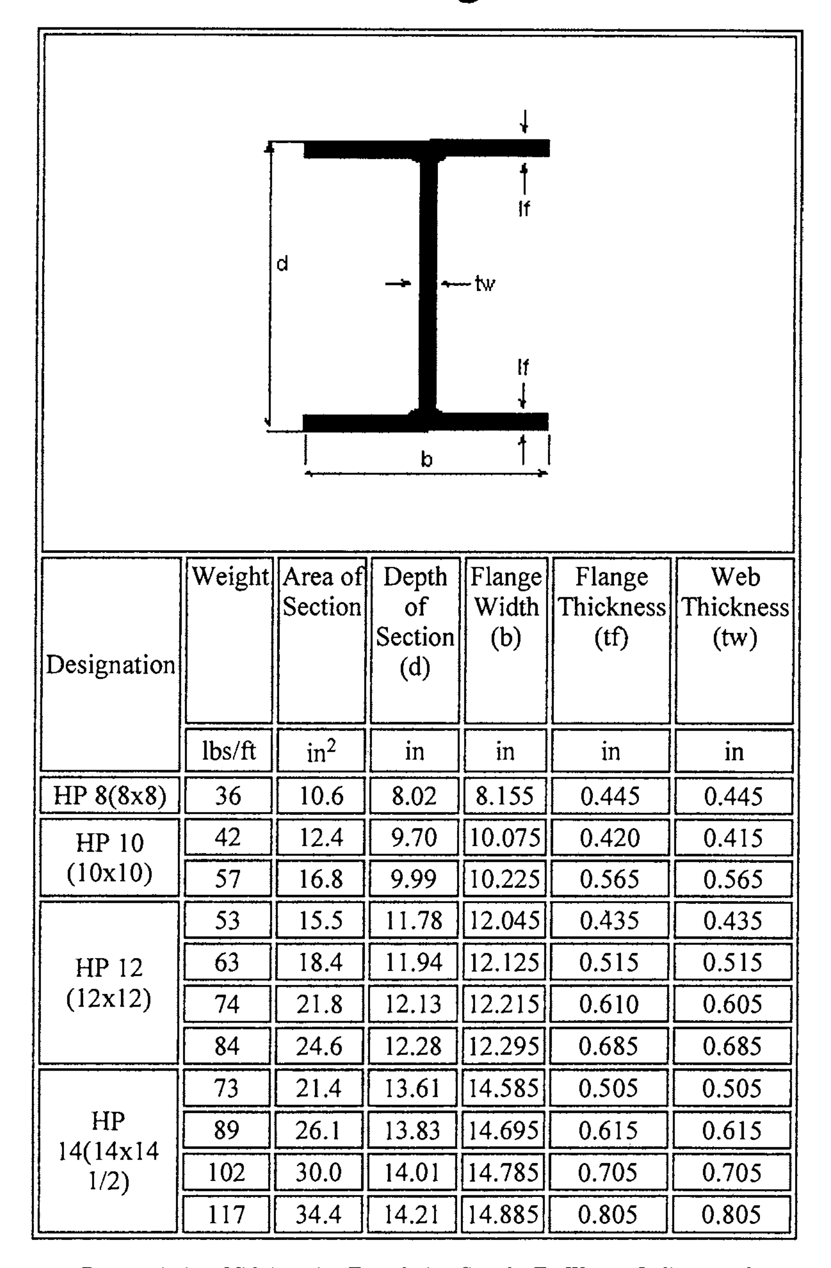





By permission, Versa-Steel, Portland, Oregon.

2.2.0 Steel H Piles

H-Bearing Pile



Designation	Weight	Area of Section	Depth of Section (d)	Flange Width (b)	Flange Thickness (tf)	Web Thickness (tw)
	lbs/ft	in^2	in	in	in	in
HP 8(8x8)	36	10.6	8.02	8.155	0.445	0.445
HP 10 (10x10)	42	12.4	9.70	10.075	0.420	0.415
	57	16.8	9.99	10.225	0.565	0.565
HP 12 (12x12)	53	15.5	11.78	12.045	0.435	0.435
	63	18.4	11.94	12.125	0.515	0.515
	74	21.8	12.13	12.215	0.610	0.605
	84	24.6	12.28	12.295	0.685	0.685
HP 14(14x14 1/2)	73	21.4	13.61	14.585	0.505	0.505
	89	26.1	13.83	14.695	0.615	0.615
	102	30.0	14.01	14.785	0.705	0.705
	117	34.4	14.21	14.885	0.805	0.805

By permission, Mid-America Foundation Supply, Ft. Wayne, Indiana, and Blytheville, Arizona.

2.2.1 Steel Wide-Flange Shapes—W6, W8, W10, W12, W14

Wide Flange Shapes
(W6, W8, W10)

Designation	Weight	Area of Section	Depth of Section	Flange		Web Thickness
			(d)	(b)	(tf)	(tw)
	lbs/ft	in	in	in	in	in
W 6 (6x6)	15	4.43	5.99	5.990	0.260	0.230
	20	5.87	6.20	6.020	0.365	0.260
	25	7.34	6.38	6.080	0.455	0.320
W 8 (8x6)	24	7.08	7.93	6.495	0.400	0.245
	28	8.25	8.06	6.535	0.465	0.285
W 8 (8x8)	31	9.13	8.00	7.995	0.435	0.285
	35	10.3	8.12	8.020	0.495	0.310
	40	11.7	8.25	8.070	0.560	0.360
	48	14.1	8.50	8.110	0.685	0.400
	58	17.1	8.75	8.220	0.810	0.510
	67	19.7	9.00	8.280	0.935	0.570
W 10 (10x5)	22	6.49	10.17	5.75	0.360	0.240
	26	7.61	10.33	5.77	0.440	0.260
	30	8.84	10.47	5.81	0.510	0.300
W 10 (10x8)	33	9.71	9.73	7.96	0.435	0.290
	39	11.5	9.92	7.985	0.530	0.315
	45	13.3	10.1	8.02	0.620	0.350
W 10 (10x10)	49	14.4	9.98	10.000	0.560	0.340
	54	15.8	10.09	10.030	0.615	0.370
	60	17.6	10.22	10.080	0.680	0.420
	68	20.0	10.40	10.130	0.770	0.470
	77	22.6	10.60	10.190	0.870	0.530
	88	25.9	10.84	10.265	0.990	0.605
	100	29.4	11.10	10.340	1.120	0.680
	112	32.9	11.36	10.415	1.250	0.755

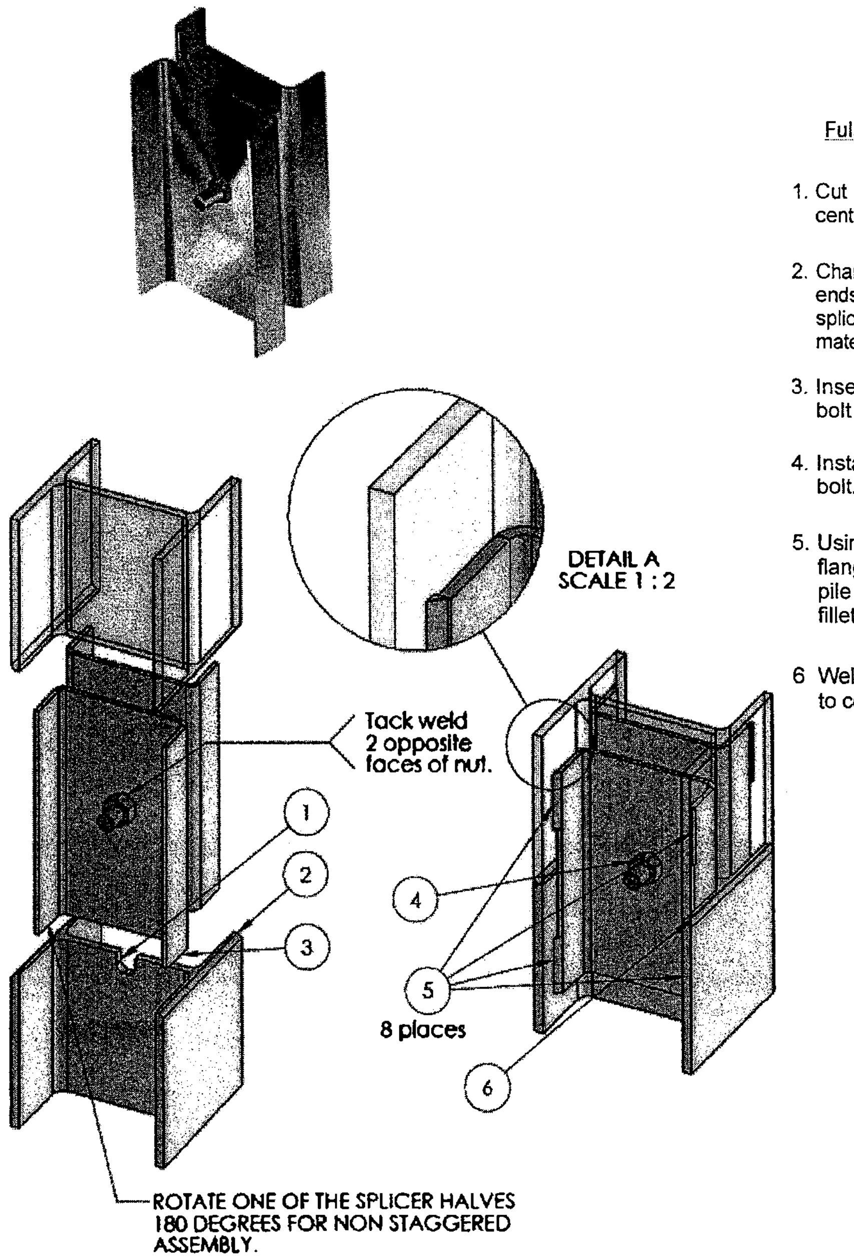
By permission, Mid-America Foundation Supply, Ft. Wayne, Indiana, and Blytheville, Arizona.

2.2.1 Steel Wide-Flange Shapes—W6, W8, W10, W12, W14 (Continued)

Wide Flange Shapes
(W12, W14)

Designation	Weight	Area of Section	Depth of Section	Flange		Web Thickness
			(d)	(b)	(tf)	(tw)
	lbs/ft	in	in	in	in	in
W 12 (12x6)	26	7.65	12.22	6.490	0.380	0.230
	30	8.79	12.34	6.520	0.440	0.260
	35	10.3	12.50	6.560	0.520	0.300
W 12 (12x8)	40	11.8	11.94	8.005	0.515	0.295
	45	13.2	12.06	8.045	0.575	0.335
	50	14.7	12.19	8.080	0.640	0.370
W 12 (12x10)	53	15.6	12.06	9.995	0.575	0.345
	58	17.0	12.19	10.010	0.640	0.360
W 12 (12x12)	65	19.1	12.12	12.000	0.605	0.390
	72	21.1	12.25	12.040	0.670	0.430
	79	23.2	12.38	12.080	0.735	0.470
	87	25.6	12.53	12.125	0.810	0.515
	96	28.2	12.71	12.160	0.900	0.550
	106	31.2	12.89	12.220	0.990	0.610
	120	35.3	13.12	12.320	1.105	0.710
W 14 (14x5)	22	6.49	13.74	5.000	0.335	0.230
	26	7.69	13.91	5.025	0.420	0.255
W 14 (14x6)	30	8.85	13.84	6.730	0.385	0.270
	34	10.0	13.98	6.745	0.455	0.285
	38	11.2	14.10	6.770	0.515	0.310
W 14 (14x8)	43	12.6	13.66	7.995	0.530	0.305
	48	14.1	13.79	8.030	0.595	0.340
	53	15.6	13.92	8.060	0.660	0.370
W 14 (14x10)	61	17.9	13.89	9.995	0.645	0.375
	68	20.0	14.04	10.035	0.720	0.415
	74	21.8	14.17	10.070	0.785	0.450
	82	24.1	14.31	10.130	0.885	0.510
W 14 (14x14)	90	26.5	14.02	14.520	0.710	0.440
	99	29.1	14.16	14.565	0.780	0.485
	109	32.0	14.32	14.605	0.860	0.525
	120	35.3	14.48	14.670	0.940	0.590

2.2.2 Steel H Pile Splices—Bolted and Welded, with Instructions



By permission, Versa-Steel, Portland, Oregon.

Welding Procedure

Full welding procedure (.pdf)

1. Cut 1.0" wide x 1.0" long notch in center of web of one pile.

2. Chamfer outside edges of flanges on ends of one or both piles to be spliced. Make chamfer to about ½ material thickness.

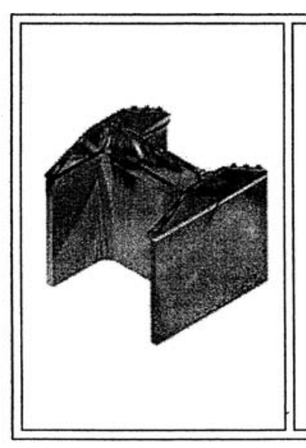
3. Insert splicer on first pile making sure bolt is completely inside notch.

4. Install next section of pile and tighten bolt.

5. Using a 70xx series rod, weld the flanges of splicer to the flanges of the pile with (TABLE)" by 3" vertical fillets.

6 Weld the outside flanges of the piles to complete.

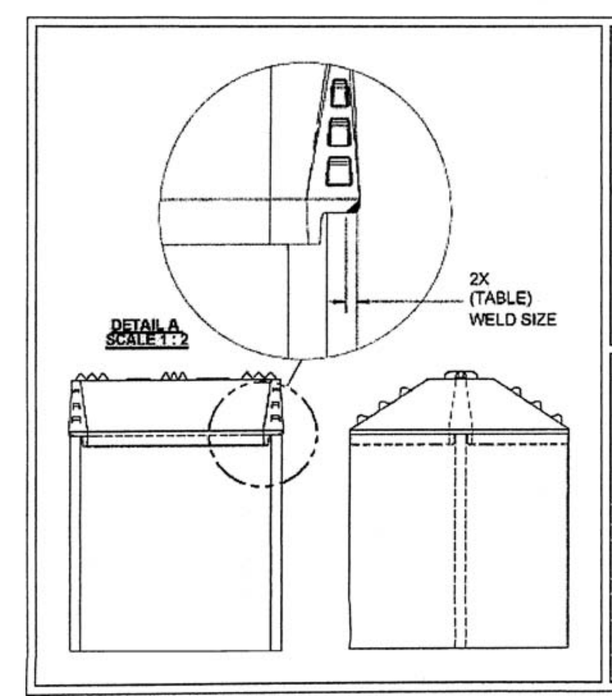
2.2.3 Steel H Pile Points—Welded



VS300N Series H-Pile Points

Versa Steel H-Pile points are made of high strength, low alloy cast steel. Cast steel is a superior material choice because it's isotropic -- its properties are uniform in all directions. Cast steel points absorb impact and transfer it uniformly to the end of the pile.

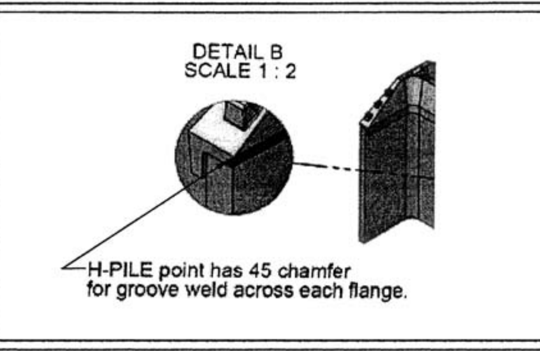
Tips are pre-beveled, eliminating pile end preparation. The weld prep is already built into the point; our castings have a 45 degree weld chamfer so there is no need to chamfer piles.



Weld Procedure

1. To insure proper seating of the tip, remove all flash from end of pile and insert tip.
2. Using a 70xx series rod, make a single pass weld (see table) across each flange on the outside only.
3. Do not weld web or inside of flanges.
4. For heavier sections, you may want to use multiple welding passes.

Full weld description available (PDF)



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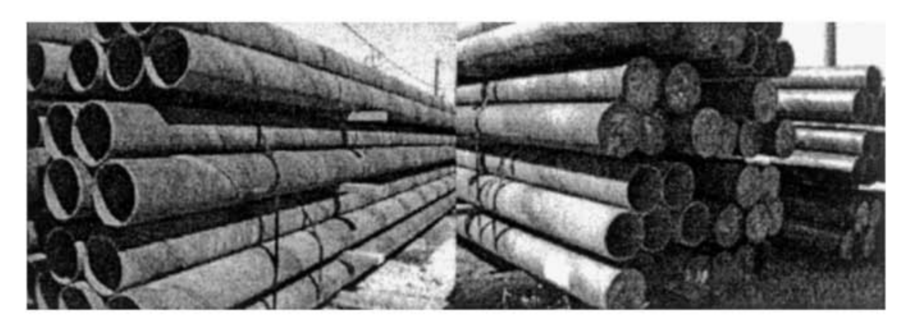
2.2.4 Steel Pipe Piles and Conical Points

Steel Pipe Piling

NAYLOR STANDARD PILING SIZES
(Weights per foot in pounds)

OUTSIDE DIAMETER	WALL THICKNESS									
Inches	0.179	0.188	0.203	0.209	0.219	0.230	0.250	0.281	0.312	0.375
mm	4.55	4.78	5.66	5.31	5.56	5.84	6.35	7.14	7.92	9.53
10" 254mm	18.8	19.7	21.2	21.9	22.9	24.0	26.0	N/A	N/A	N/A
10¾" 273mm	20.2	21.2	22.9	23.5	24.6	25.8	28.0	N/A	N/A	N/A
12" 305mm	22.6	23.7	25.6	26.3	27.6	28.9	31.4	35.2	38.9	N/A
12¾" 324mm	24.0	25.2	27.2	28.0	29.3	30.8	33.4	37.4	41.4	49.6
14" 356mm	26.4	27.7	29.9	30.8	32.2	33.8	36.7	41.2	45.6	54.6
16" 406mm	30.2	31.7	34.2	35.2	36.9	38.7	42.1	47.2	52.3	62.6
18" 457mm	34.1	35.8	38.6	39.7	41.6	43.7	47.4	53.2	58.9	70.6
20" 508mm	37.9	39.8	42.9	44.2	46.3	48.6	52.7	59.2	65.6	78.6

Other sizes and wall thicknesses are available upon request.





CONICAL POINTS FOR PIPE PILES

2.3.0 Precast Concrete Piles

Design Requirements. Adequate plant inspection reports should accompany each pile shipment, identifying the piles and certifying that they meet the design specifications including such things as the amount of reinforcing steel, 28-day concrete strength, and effective pre-stress. Piles should be marked or stamped with the date of manufacture. Inspection reports should come from an independent testing agency and not from the manufacturer.

Lengths. Precast piles will be shipped to the jobsite according to specified or approved ordered lengths. Each pile should be of the full ordered length except when sectional-type piles are permitted. Sometimes piles are ordered with sufficient extra length to permit stripping back the concrete and exposing the reinforcing steel for the pile-to-cap connection (see under Pile Installation). Ordered lengths may be somewhat larger than anticipated driven lengths to allow for variations in subsoil conditions.

Dimensions. Piles should be of the shape and size specified.

Tolerances. Piles should be straight within specified tolerances. Butt ends should be square to the longitudinal axis and free of any major surface irregularities.

Chamfers. All corners or edges of square piles should be chamfered. The width of the chamfer should be limited to about 1.5 in (38.1 mm) so that the reduction in any side dimension due to chamfer is not more than about 2 in (50.8 mm).

Damage. Check piles for detrimental cracks, spalling, slabbing, or other damage. Hairline cracks are normal but should not be too numerous.

2.4.0 Typical Specifications for Cast-in-Place Concrete Piles

Design Mix. A design mix with results of tests on standard cylinders should be furnished by the contractor. Copies of these data should be made available to the inspector at the start of pile installation.

Concrete Production Facilities. Concrete may be mixed in portable mixers brought to the pile locations, but generally it will be ready-mixed. Ready-mix concrete may be (1) batched and mixed at a central plant and delivered to the pile locations in agitating or nonagitating trucks (central-mixed), (2) batched at a central plant and mixed in a truck mixer in transit to or after reaching the jobsite (truck-mixed), or (3) partially centrally mixed with mixing completed in a truck mixer in route to the job or on the jobsite (shrink-mixed). The central plant may be located on the jobsite. The concrete batch and mixing plant should be inspected for adequacy of storage facilities for materials, accuracy, and reliability of batching equipment, condition of mixing equipment, and proper operational procedures.

Storage Facilities. Cement must be kept dry whether it is stored in bulk containers or in bags. To avoid contamination, stockpiles of aggregates that have been cleaned, graded, and prepared for batching should be on a hard, clean base with the area around the stockpiles spread with a bedding material of sand, gravel, or rock. Side slopes of stockpiles should not exceed 7 in/ft (583 mm or less per meter) to prevent segregation. Coarse aggregate should be separated by type and size gradation. Overlapping of stockpiles should be prevented and suitable drainage should be provided. All reasonable precautions should be taken to keep the moisture content of aggregates as nearly uniform as possible.

Batching Equipment. Concrete is usually batched by weight. Batching scales should have a recent calibration and certificate of inspection and must be clean and free of interference by other objects. Separate weight-batching facilities should be provided for cement. Batch-weight recording and cutoff devices must operate accurately. The bottom of batch bins must be fully sloped in all directions. Water-metering devices, whether at a central mixing plant or mounted on a truck mixer, must be accurate and equipped with indicating dials and totalizers.

Mixing Equipment. All mixing equipment, whether stationary or truck-mounted, must be in good operating condition. The interior of drums should be clean, and mixing blades should not show signs of wear in excess of 1 in (25.4 mm). Truck mixers must be equipped with a reliable revolution counter.

Operations. All materials must be accurately batched, and batching should be by weight. Admixtures, if required, must also be accurately measured. Mixing drums must be cleaned after each use to prevent an accumulation of hardened concrete on the blades. All washwater must be removed

from the mixing drum prior to batching. Cement should be used on the basis of first in-first out. The free-water content of the aggregates should be included as part of the total mix water. Aggregates should be allowed sufficient time to drain, and it may be necessary to have a moisture meter in the sand batcher to monitor moisture content. Proper equipment and methods must be used for handling aggregates to avoid segregation and breakage. Segregation of coarse aggregate can be reduced by separating it into several size fractions and batching them separately. Finished screening of aggregates at the batcher is recommended to avoid problems of segregation and contamination.

Concrete Materials. Materials including cement, sand, coarse aggregate, and water should be inspected for compliance with specifications and accepted practice.

Cement. Cement must be of the type specified or permitted with the approval of the engineer. Mill certificates should be furnished to show that cement conforms with the requirements of the specifications and ASTM C150, Standard Specifications for Portland Cement. Type IV cement should not be used for pile concrete. Type III, or high-early, cement may be permitted for cast-in-place concrete test piles to get a fast gain in strength. Type II or Type V cement may be specified for sulfate exposure.

Cement remaining in bulk storage for more than 6 months or cement stored in bags longer than 3 months should be retested before use to ensure that it meets the requirements of ASTM C150. Cement should not be used directly from the mill if it is still hot. The cement should be allowed to cool before using to reduce the possible occurrence of false sets.

Cement should be inspected for lumps caused by moisture. Cement bags should be inspected for rips, punctures, or other defects. If cement is to be batched by bag, the weights of bags should be spot-checked and should not vary by more than 3 percent.

Sand. Sand should be clean, sharp, well graded, and free of silt, clay, or organic material. The specific gravity and/or fineness modulus may be specified for special mixes such as reduced coarse aggregate concrete.

Coarse Aggregate. Specifications may permit gravel or crushed stone. The use of crushed rock aggregate requires more cement and sand for comparable workability. Air entrainment also improves workability. Lightweight aggregates are not recommended, and slag aggregates are not generally used. Alkali-reactive aggregates or aggregates from shales, friable sandstone, chert, and clayey or micaceous rock should not be permitted. Aggregates should be uncoated and free of silt, clay, organic material, and chemical salts. The specific gravity of the coarse aggregate may be specified. Aggregates should be well graded with a maximum size of $^3/_4$ in (19.05 mm) and with the amounts of aggregates less than $^3/_{16}$ in (4.762 mm undersize) held uniform and within 3 percent.

Water. As a general rule, mix water should be potable. It should contain no impurities which would affect the quality of the concrete. It should not have a sweet, saline, or brackish taste or contain silt or suspended solids. Very hard water may contain high concentrations of sulfate. Well water from arid regions may contain harmful dissolved mineral salts. If questionable, the water can be chemically analyzed. The quality of the water can be checked by comparing the strength of concrete reached at various ages for a mix using the water of unknown quality with the results of similar age tests on a mix made with water which is known to be acceptable. Impurities in mix water may affect both the compressive strength of the concrete and its setting time.

Admixtures. The authorized or mandatory use of admixtures will be noted on the mix design report. Special admixtures such as retarders and fluidizers may be required for pumped concrete.

Cold-Weather Operations. The minimum temperature of fresh concrete as mixed should be about 45°F (7.2°C) for air temperatures above 30°F (−1.1°C), 50°F (10°C) for air temperatures from 0 to 30°F (−17.2 to −1.1°C), and 55°F (12.7°C) for air temperatures below 0°F (−17.2°C). Frozen aggregate or aggregates containing lumps of ice should be thawed before being used. It may be necessary to preheat the mix water and/or the aggregate. For air temperatures between 30 and 40°F (−1.1 and 7.2°C), it is usually necessary only to heat the water to a maximum of about 140°F (60°C). For air temperatures below 30°F (−1.1°C), the water can be heated to 140 to 212°F (60 to 100°C) and the aggregate to about 45 to 55°F (7.2 to 12.7°C). Overheating should be avoided. If both the mix water and the aggregates are preheated, it is recommended that the water be mixed with the aggregates before adding the cement to avoid a flash set. The temperature of the water-aggregate mixture should not be higher than 80°F (26.6°C) and preferably about 60°F (15.5°C).

Hot-Weather Operations. If the temperature of the concrete during mixing is above 80°F (26.6°C), it could result in increased water demand (slump loss) or an accelerated set. The easiest way to control and reduce the concrete temperature is by using cold mix water, which can be

achieved by mechanical refrigeration or by using crushed ice as part or all of the mix water. Mixing time should be kept to a minimum, and mixing drums, water tanks, and pipe should be painted white.

Mixing Time. Mixing time starts when the water is added to the mix and should be adequate but not excessive. Minimum mixing times vary with the size and type of the mixer and range from 1 to 3 minutes. Maximum mixing times can range from 3 to 10 minutes. For stationary mixers, minimum mixing time can be established by tests on mixer performance. For truck-mixed concrete, complete mixing requires from 50 to 100 revolutions of the drum at mixing speed. Check the manufacturer's plate on the mixer. If, after mixing, drum speed is reduced to agitation speed or stopped, the drum should be rotated at mixing speed for from 10 to 15 revolutions just before concrete is discharged.

Elapsed Time. For normal temperatures, the total time from start of mixing to discharge should not exceed about 1½ hours and should be reduced as temperatures increase. The mix should be discharged before 300 revolutions of the drum.

Slump. Slump tests should be made periodically in accordance with ASTM C143, Standard Method of Test for Slump of Portland Cement Concrete, to ensure that concrete has the specified slump for proper placement in pile casings, shells, or holes. The slump for concrete as delivered to the top of the pile casing or hole should be 5 in (127 mm) for conventional concrete or 4 in (101.6 mm) for reduced coarse aggregate concrete, both with a tolerance of +2 in, −1 in (+50.8 mm, −25.4 mm). Special-type piles may require concrete having different slumps. See Special-Type Piles. Sometimes it is advisable to check the slump just before adding the final water at the jobsite to avoid too high a slump or a wet mix.

Slump Loss. Slump loss can be caused by overmixing, hot weather, pumping through long lines, or delays in delivery and placement of concrete. Overmixing can and should be avoided. If necessary, all the mix water can be added and all mixing done upon delivery at the jobsite. This could prevent overmixing and may help in eliminating slump loss due to hot weather. If concrete is to be pumped to the pile locations, the slump should be increased without changing the water-cement ratio or concrete strength to compensate for slump loss during pumping. All preparations should be made for depositing concrete upon delivery, and delivery schedules should be arranged to eliminate delays in placing concrete.

Retempering. The addition of water to the concrete mix to compensate for slump loss resulting from delays in delivery or placing is permissible provided the design water-cement ratio is not exceeded and the concrete has not attained its initial set. Initial set is not to be confused with a false set, when the concrete appears to stiffen but can be made workable with agitation.

Delivery Tickets. A delivery ticket must accompany each load or batch of concrete. The delivery ticket is for the purchaser, but the inspector should be furnished a copy. It should include sufficient data to identify the producer, project, contractor (purchaser), truck mixer used, and specified concrete mix or strength. Other information which should be on the delivery ticket is the date of delivery, type and brand of cement, maximum aggregate size, weights of cement, sand, and coarse aggregate, type and amount of admixtures, quantity of water, time batched, reading of revolution counter and time when water was first added, volume of batch, and amount of water added by the receiver. The inspector should note the times of delivery and placement and the air temperature.

Concrete Strength. Standard cylinders for compression tests should be made periodically or as specified in accordance with ASTM C31, Standard Method for Making and Curing Concrete Test Specimens in the Field, to ensure that concrete of required strength is being furnished. The frequency for making test cylinders will vary with the job size and other factors, but generally a test set (minimum of two cylinders) should be made for each daily pour or for every 50 yd^3 (38.2 m^3) placed. Also a test set should be made for each age at which compression tests are to be run. The inspector should ensure that cylinders are properly cast, handled, stored, sealed, packaged for shipment, and shipped so as not to invalidate test results. For strict concrete control, test specimens should be cast in cast-iron or tin-can molds. Although widely used, cardboard or paper molds are not recommended for molding test cylinders for strict concrete control. If cardboard molds are used, they should conform with ASTM C470, Specifications for Molds for Forming Concrete Test Cylinders Vertically. Jobsite curing or the use of cardboard molds may contribute to low strength-test results. Grout strengths for special-type piles are determined by standard cube tests in accordance with ASTM C91, Specification for Masonry Cement. (See Auger-Grout Pile, Cast-in-Place Pile, and Minipiles under Special-Type Piles.)

Results of Tests. The pile inspector should be furnished with copies of the results of all concrete compression tests as called for in the specifications. It is advisable to obtain 3- and 7-day results at the beginning of the job in order to detect trends in concrete strengths. The results of 7-day tests are also valuable in monitoring concrete strength trends as the job progresses so that, if necessary, remedial measures can be taken before too much concrete is placed.

Strength Variations. Variations in concrete strength as determined by standard cylinder tests are normal. Several criteria are used to determine the acceptability of variations. For example, the concrete is considered satisfactory if the average of three consecutive tests is equal to or greater than the required 28-day strength and no test falls below the required 28-day strength by more than 500 psi (3447 kPa). Another acceptance criterion is that 80 percent of the tests show strengths greater than the design strength and that not more than 1 test in 10 is less than the required 28-day strength. A third is that the average strength from consecutive tests is greater than the required 28-day strength. ACI 214.3-88 provides recommendations on evaluating concrete strength-test results. If the test results show that concrete strength is below that specified, the cause of low-strength concrete should be investigated. Low strength could be caused by unsatisfactory materials, by improper batching and mixing, or by the use of excess water in the mix. Low cylinder breaks could also result from improperly preparing, curing, handling, or testing cylinder specimens.

Verification of Concrete Strengths. If the results of standard cylinder tests are low, cores can be removed from piles for testing. Core tests are considered satisfactory if the average of three cores is equal to or greater than 85 percent of the required 28-day strength and if no core strength is less than 75 percent of the specified 28-day strength. The results of tests on cores are normally lower than those on standard cylinders owing to microfracturing of the concrete. It should be noted that pile concrete in a long steel shell embedded in the ground will cure at a rate slower than that for test cylinders or exposed concrete. Curing conditions are ideal, but the rate of strength gain is lower than normal. Concrete strength in completed piles can also be checked by various nondestructive methods such as penetration-resistance tests. See ASTM C803, Method of Tests for Penetration Resistance of Hardened Concrete.

Courtesy McGraw-Hill: *Field Inspection Handbook*, Brock Levy, Sutcliffe.

2.5.0 Handling, Storage of Timber, Precast, Steel, and Concrete Piles

Unloading. Timber piles may be unloaded by controlled roll-off. Dumping should not be permitted.

Handling. Generally treated timber piles should not be handled with timber tongs, cant hooks, peaveys, or pile chains. Piles should be handled so as to avoid puncturing or breaking through their outer treated portion. AWPA standard M4-80 permits the use of pointed tools provided that the side surfaces of the pile are not penetrated more than 1/2 in (12.7 mm). This may be difficult to control. Treated timber piles should not be dragged along the ground.

Storage. Timber piles in storage for any length of time should be on adequate blocking and supported to avoid permanent bends. Piles should be stacked on treated or nondecaying material and with an air space beneath them. Storage areas should be free of debris, decayed wood, and dry vegetation (this presents a fire hazard) and should have sufficient drainage to prevent the piles from lying in water.

Precast Piles

Unloading. Precast piles should be unloaded by lifting them in a horizontal position. Dumping or rolling off the precast piles should not be permitted.

Handling. Precast piles should be handled with proper slings attached to designated pickup points or inserts. Impact loads should be avoided.

Storage. If precast piles are stored on blocking, it should be placed at designated support points to avoid overstressing and cracking the piles.

Steel Pipe and Tube Piles

Unloading. Controlled dumping or roll-off unloading of pipe or tube piles may be permitted.

Handling. Sufficient pickup points should be used to avoid bends in pipe or tube piles. A closed-end pile should not be dragged along the ground with the open end first.

Steel H Piles

Unloading. H piles should be unloaded by lifting them in a horizontal position. Dumping piles should be prohibited.

Handling. H piles lifted in a horizontal position should have their webs vertical to avoid bending. Coated H piles must be carefully handled so as to avoid damage to the coating.

Storage. H piles should be stored on adequate blocking. Nesting of piles with their flanges vertical is recommended.

Pile Shells

Unloading. Dumping of pile shells should not be permitted, but they may be roll-off unloaded.

Handling. Pile shells should be handled at all times so as to avoid permanent deformations. A closed-end shell should not be dragged along the ground with the open end first.

Storage. Pile shells should be stored out of mud or standing water. If in storage for a long period of time, shells should be protected from the elements.

Handling Cement and Concrete for Pilings

Cement

Storage. Bag cement must be stored off the ground on adequate racks and protected from the elements, especially moisture.

Concrete Aggregates

Handling. Aggregates should be handled so as to avoid breakage, segregation, and contamination. The required gradation must be maintained.

Storage. See Concrete Production Facilities: Storage Facilities under Pile Material.

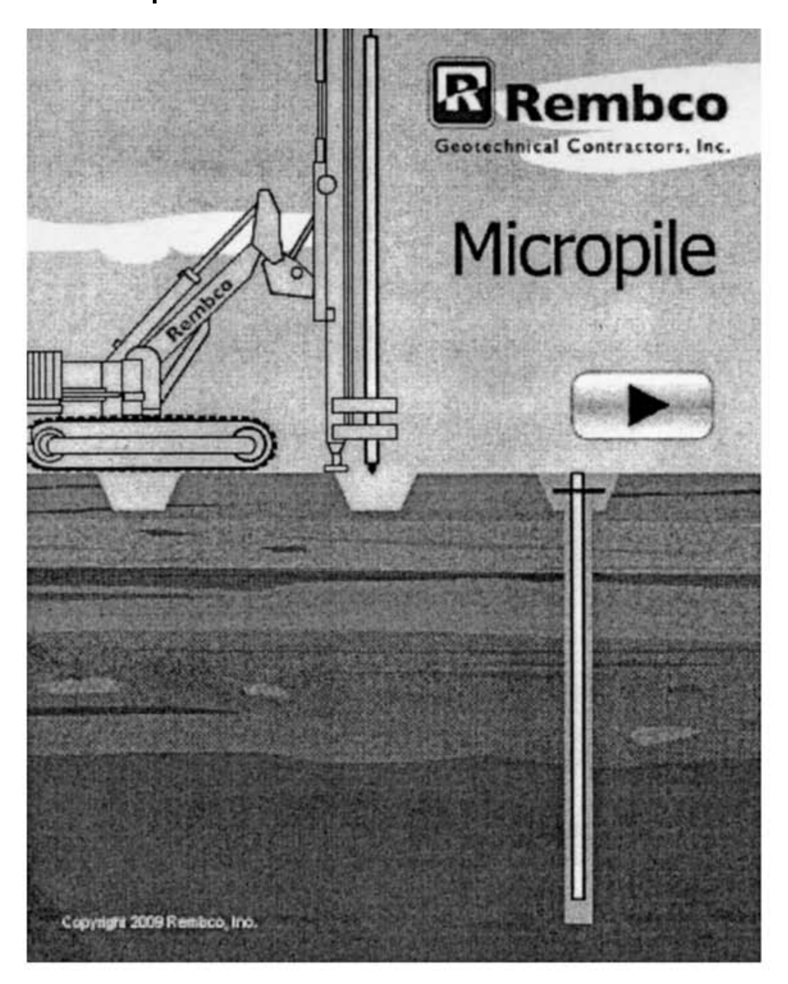
Handling Reinforcement

Reinforcement

Handling. Reinforcing steel should be handled in bundles with appropriate lifting slings located at sufficient pickup points to avoid permanent bending. Bundles should not be broken until the steel is to be used. All necessary precautions must be taken to maintain the identification of the steel after the bundles have been broken. This can be done by keeping the steel separated according to type, size, and length with a tagged piece in each stack.

Storage. Reinforcing steel should be stored off the ground on suitable racks or blocking so as to avoid permanent bends. The steel should be stored so as to prevent excessive rusting and contamination by dirt, grease, or other bond-breaking coatings.

2.6.0 Minipiles and Micropiles



Micropiles are small diameter drilled and grouted friction piles. Each pile includes steel elements that are bonded into the bearing soil or rock – usually with cement grout. The bearing stratum is logged during installation drilling to assure that bearing capacity is adequate. Micropiles do not rely on end-bearing capacity, so there is no need to establish the competency of rock beyond bond-depth. They can be installed quickly in virtually every type of ground using highly adaptable mobile drilling equipment. These steel piles have working capacities up to 250 tons.

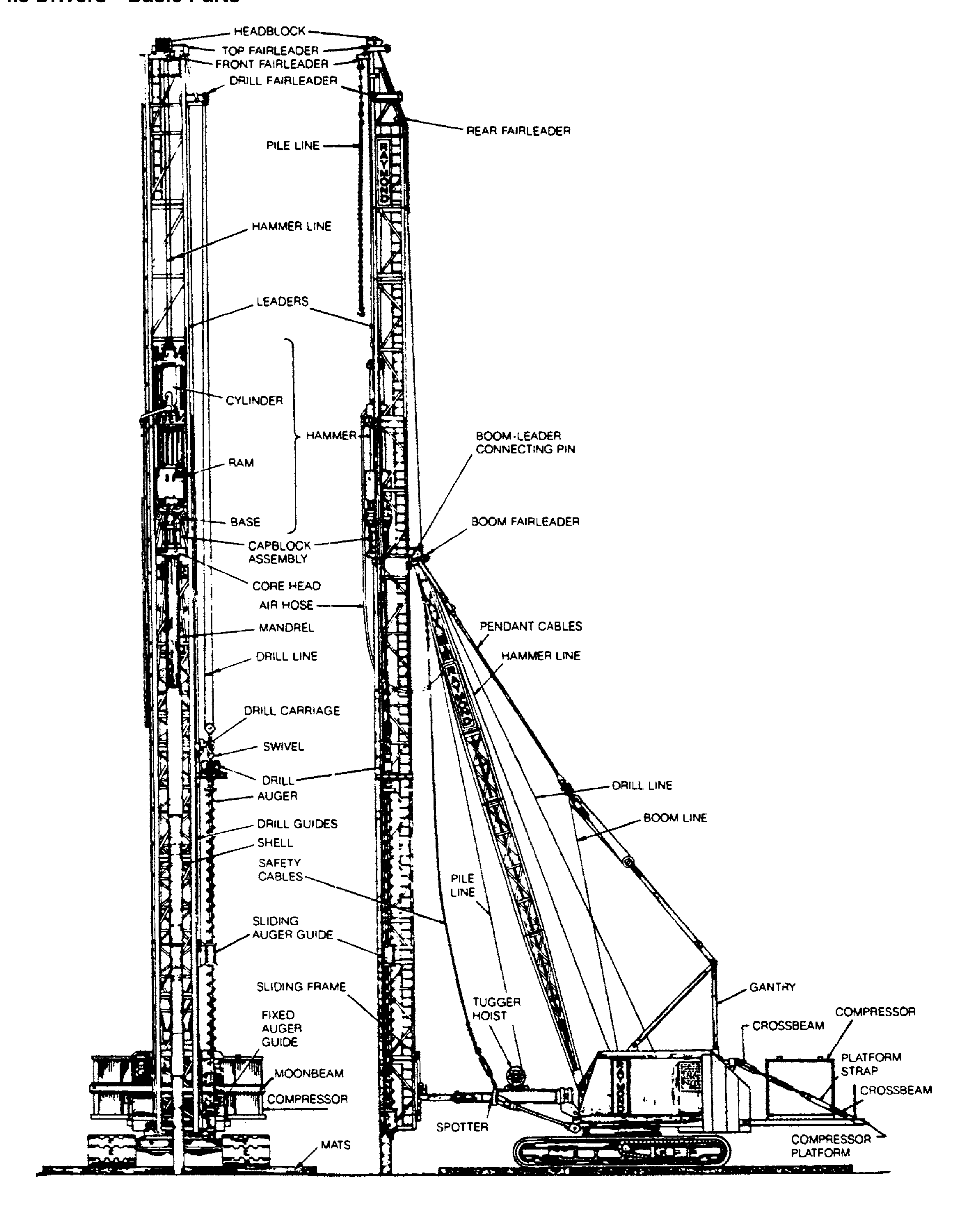
Rembco uses micropiles (minipiles) as an economical alternative to large diameter drilled shaft foundations, especially in difficult ground conditions, karst geology, or restricted access situations.

Micropiles - Minipiles Setup Sequence:
Drilled into bedrock, micropiles or minipiles bond to the rock socket wall for load transfer.

- The casings of the minipiles are advanced as piles are drilled into site's bedrock.
- Drill pipe is removed, which leaves casing for mini or micro piles setting in bedrock.
- A reinforcement load bar is lowered into casings of the micro piles, for added capacity.
- Cementitious grout is pumped or pressure feed into the minipiles casings, bottom up.
- The casings for the micro piles are lifted to top of bedrock, allows bonding to the bar.
- Excess steel is cut from the tops of micropiles; piles are capped to engineer's design.
- A select number of piles are load tested to prove the engineering load design.

By permission, Rembco Geotechnical Contractors, Knoxville, TN.

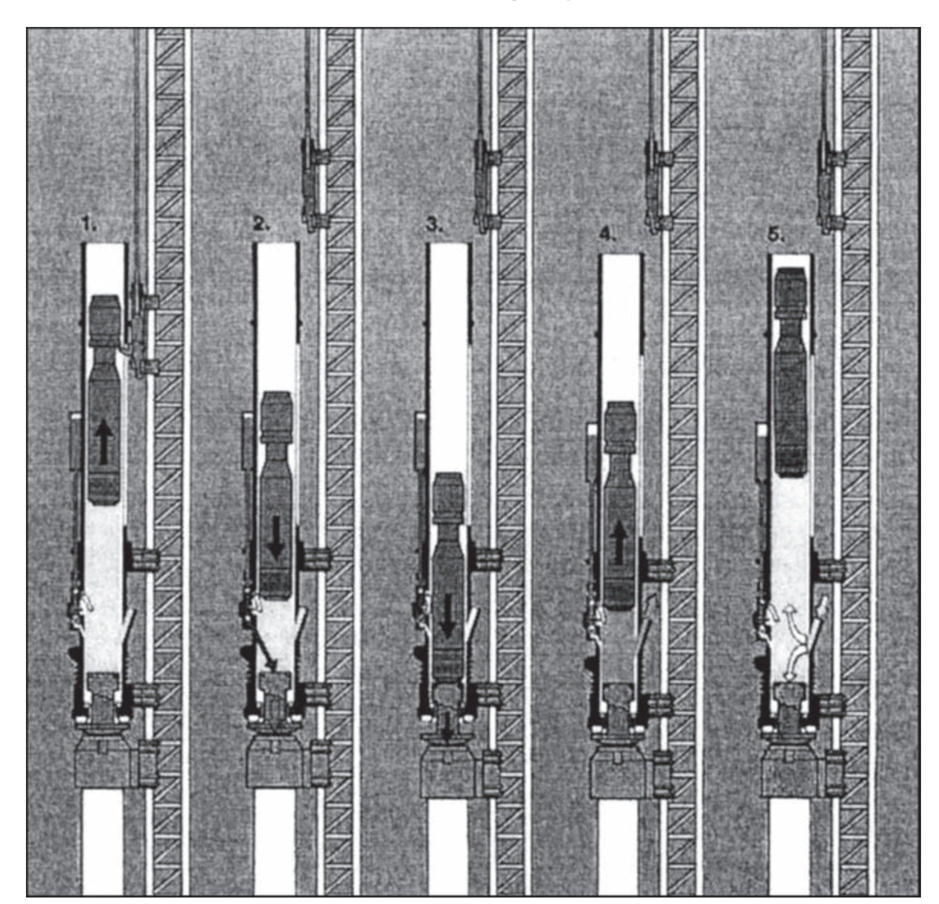
2.7.0 Pile Drivers—Basic Parts



2.7.1 Pile Driving Hammer Types

1. *The drop hammer* Rarely used, except for installing compacted-concrete piles.
2. *Single-acting hammers* Powered by steam or air pressure, which is used to raise the hammer ram for each down stroke. Gravity and the weight of the hammer deliver the kinetic energy required to drive the pile.
3. *Double-acting hammers* Generally powered by compressed air or hydraulics, which provides the power to raise the hammer ram and accelerate its fall.
4. *Vibratory hammers* Paired, oscillating rotating weights connected to the pile delivers anywhere from 0 to 2000 vibrations per minute at low frequency or from 0 to 8000 vibrations per minute for high-frequency hammers to drive the pile to design depth. This type hammer is effective only in granular or cohesiveless soils.

2.7.2 Diesel Pile Hammer Operation—A Five-Stage Cycle



Diesel pile hammers are operating as follows:

1. Raising of piston

For starting the Diesel pile hammer, the ram weight (piston) is raised by means of a tripping device and automatically released at a given height.

2. Injection of Diesel fuel and compression

While dropping, the piston will actuate the pump lever so that a given quantity of Diesel fuel is sprayed on top of impact block. After passing the exhaust ports, the piston will start compressing the air in the cylinder chamber.

3. Impact and explosion

The impact of the piston on the impact block will atomize the Diesel fuel in the combustion chamber. The atomized fuel will ignite in the highly compressed air. The resulting explosive energy will force up the piston.

4. Exhaust

While moving upwards, the piston will expose the exhaust ports. Exhaust gases will escape and the pressure in the cylinder will equalize.

5. Scavenging

The piston keeps jumping upwards and will draw fresh air through the exhaust ports for scavenging the cylinder, while also releasing the pump lever. The pump lever returns to it's starting position, so that the pump will again be charged with fuel.

Source: Hammersteel, St. Louis, Missouri.

2.7.3 Double-Acting Hydraulic Hammer-Type Pile Driver

The ram in a hydraulic hammer is lifted by hydraulic pressure, and on the downward stroke, additional energy is added to the ram. Pressurized nitrogen pushes the ram down.

2.7.4 Vibratory Pile Drivers

These types of pile drivers use vibration to penetrate the soil strata, using the theory of vibration to reduce the friction between the pile and the soil. These vibrations create soil liquefaction to some degree, causing soil particles to "float" and provide a significant decrease in resistance between the soil and the pile. The pile can be driven into the ground with very little added weight or pressure. This vibratory head generates oscillations inside a vibration case where eccentric weights are gear-driven by one or more motors. The crane from which the vibratory driver is attached must be isolated from the vibration case by rubber or spring cushions. The vibratory pile driver is frequently used to extract previously driven piles since the upward pull is substantially reduced. Vibratory pile drivers work best in noncohesive soils such as gravel and sand. These types of pile drivers also work quite well in water-saturated soils.

2.8.0 Jetting

The practice of jetting, applying a pressurized water jet at the toe of the pile, can greatly facilitate the driving of piles in some instances. The object of jetting is to loosen the soil, thereby reducing the resistance of the toe of the pile. The effectiveness of jetting depends upon the density of the soil and the availability of adequate water pressure.

2.8.1 Low-Pressure Jetting

This method is used in dense noncohesive soils in combination with a vibratory pile driver. Drivers with variable eccentricity are recommended when low-pressure jetting is used. Water pressure providing a pressure of 20 bar (0.42 lb/ft^2) with a volume of 120 to 240 L (31.7 to 63.4 gal) per minute will be required; to be delivered through special nozzles.

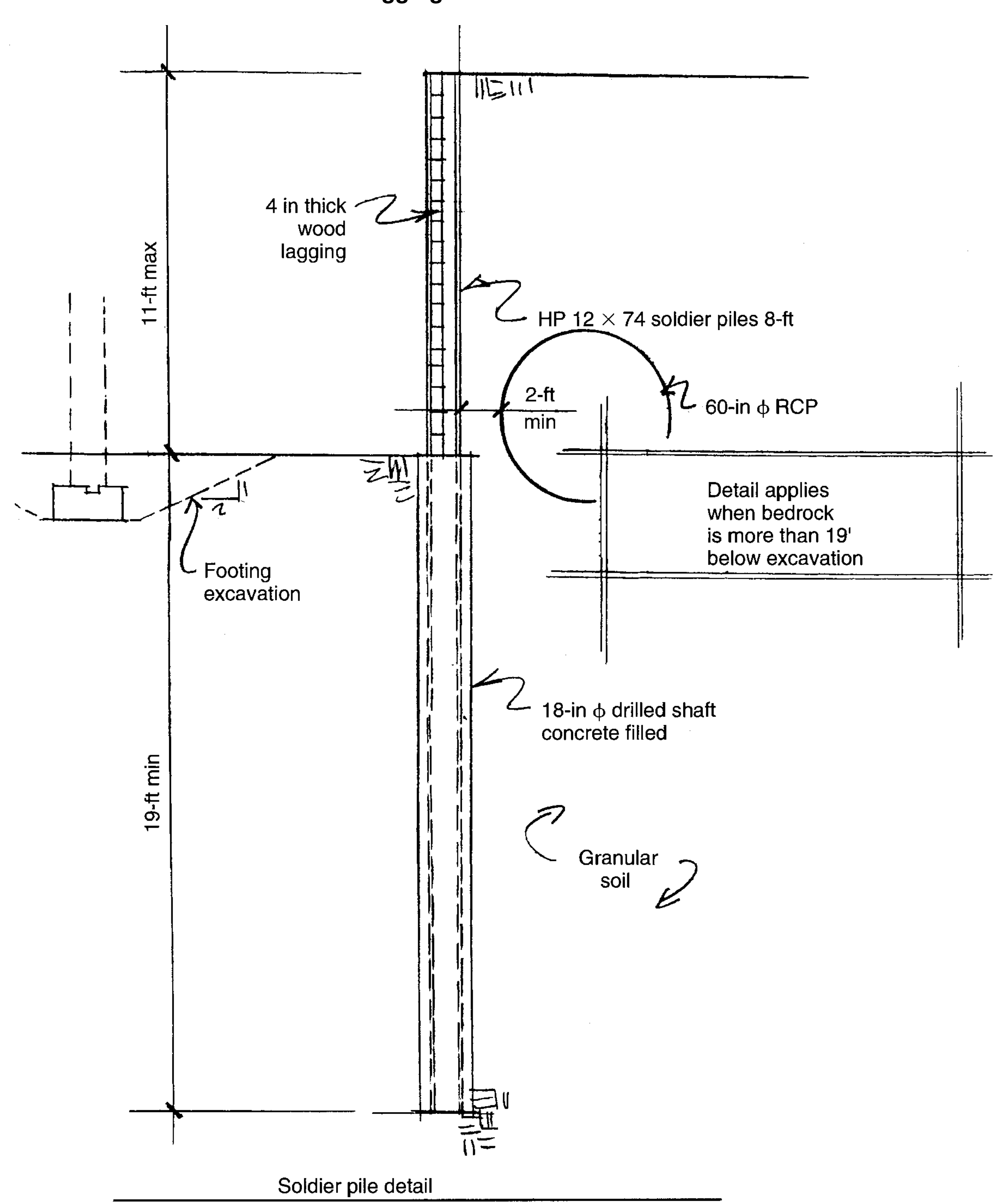
2.8.2 High-Pressure Jetting

This method employs pressure of 250 to 500 bar (5.22 to 10.44 lb/ft^2) and a water volume of 60 to 120 L/min (15.8 to 31.7 gal/min) also to be delivered through special nozzles.

2.9.0 Soldier Piles

Steel piles are either driven or drilled in at intervals along a wall for the attachment of wood lagging or sheet steel to allow excavation to continue similar to a row of soldiers standing at attention.

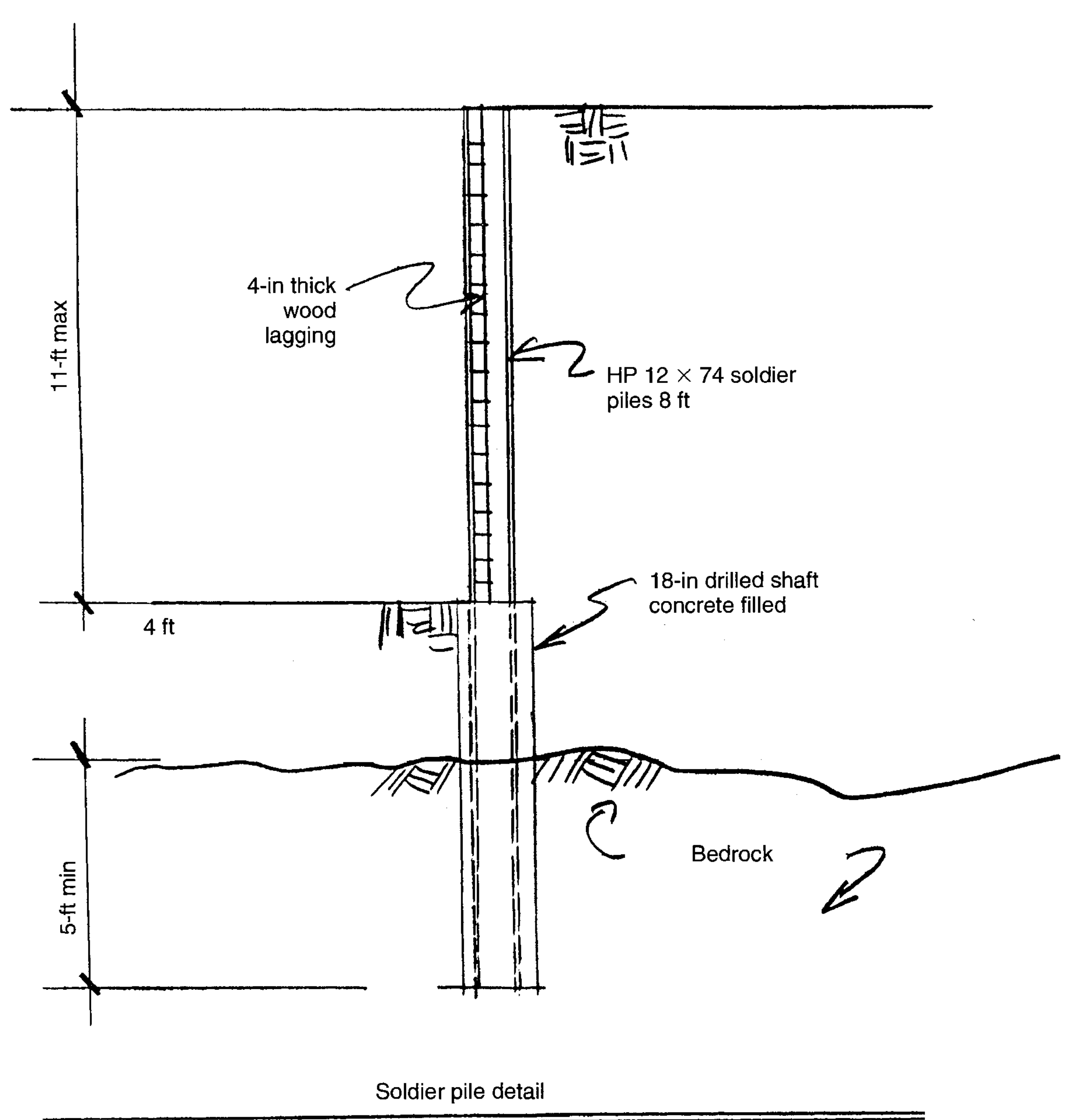
2.9.1 Typical Steel Soldier Pile with Wood Lagging



Soldier pile detail

Scale: 1/4 in = 1 ft

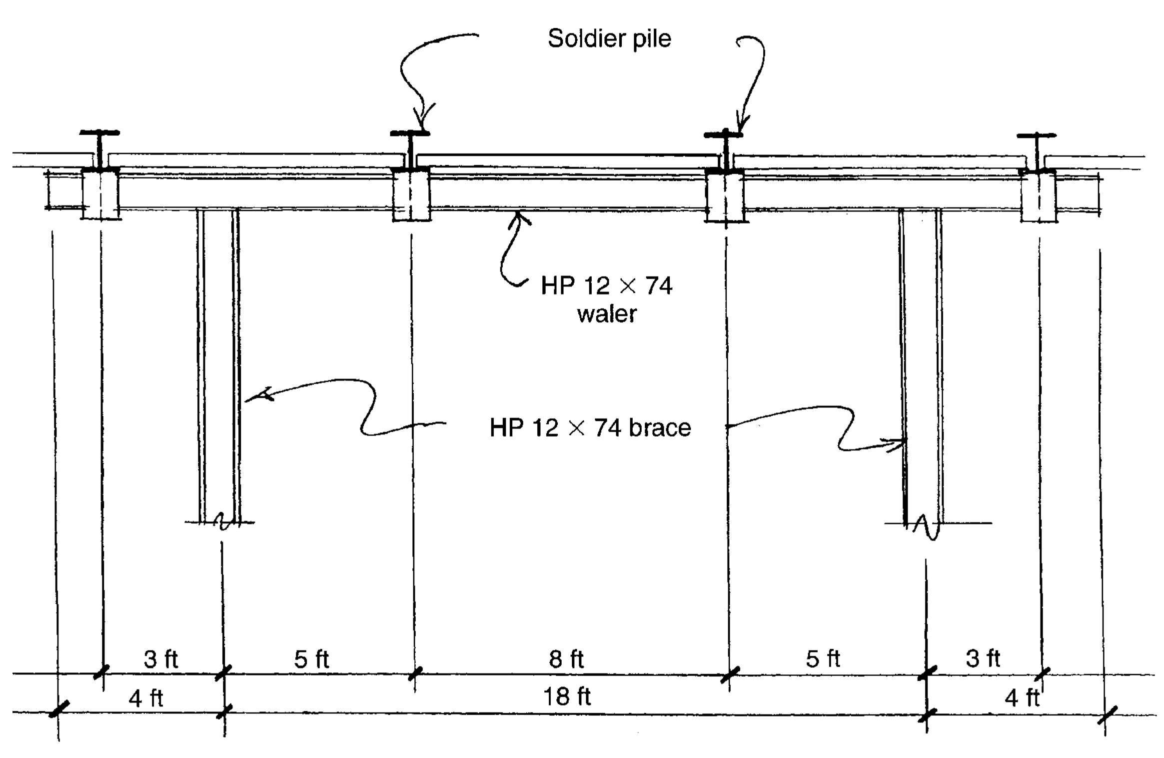
2.9.2 Typical Soldier Pile Drilled into Rock



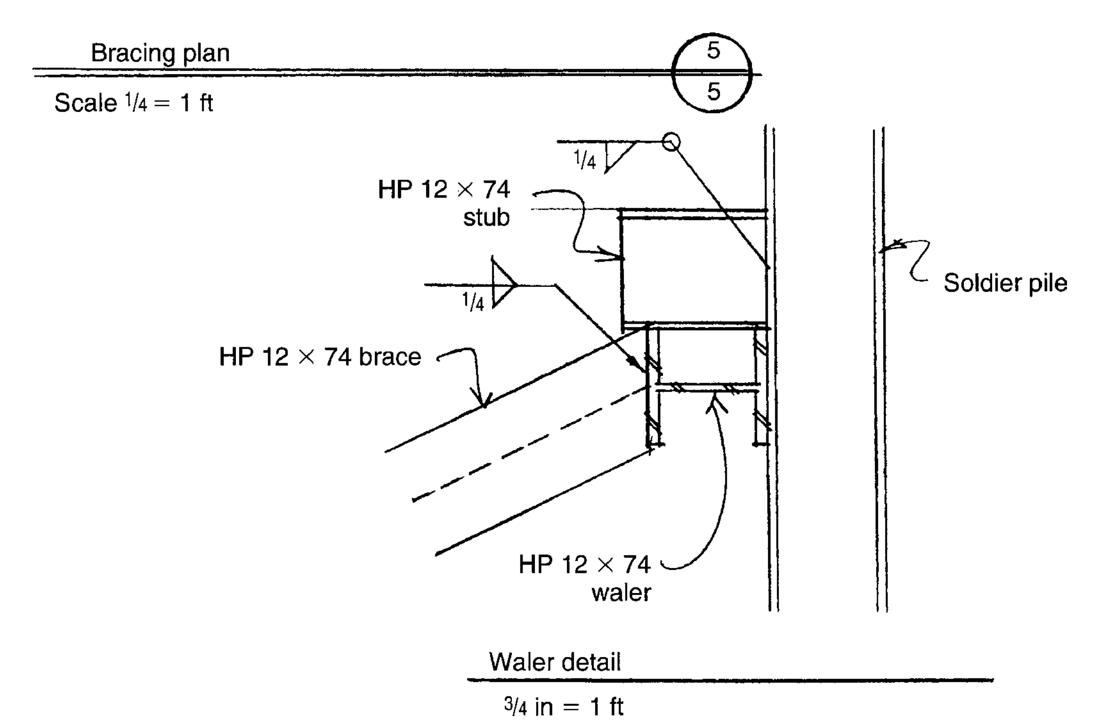
Soldier pile detail

Scale: 1/4 in = 1 ft

2.9.3 Typical Braced Soldier Pile

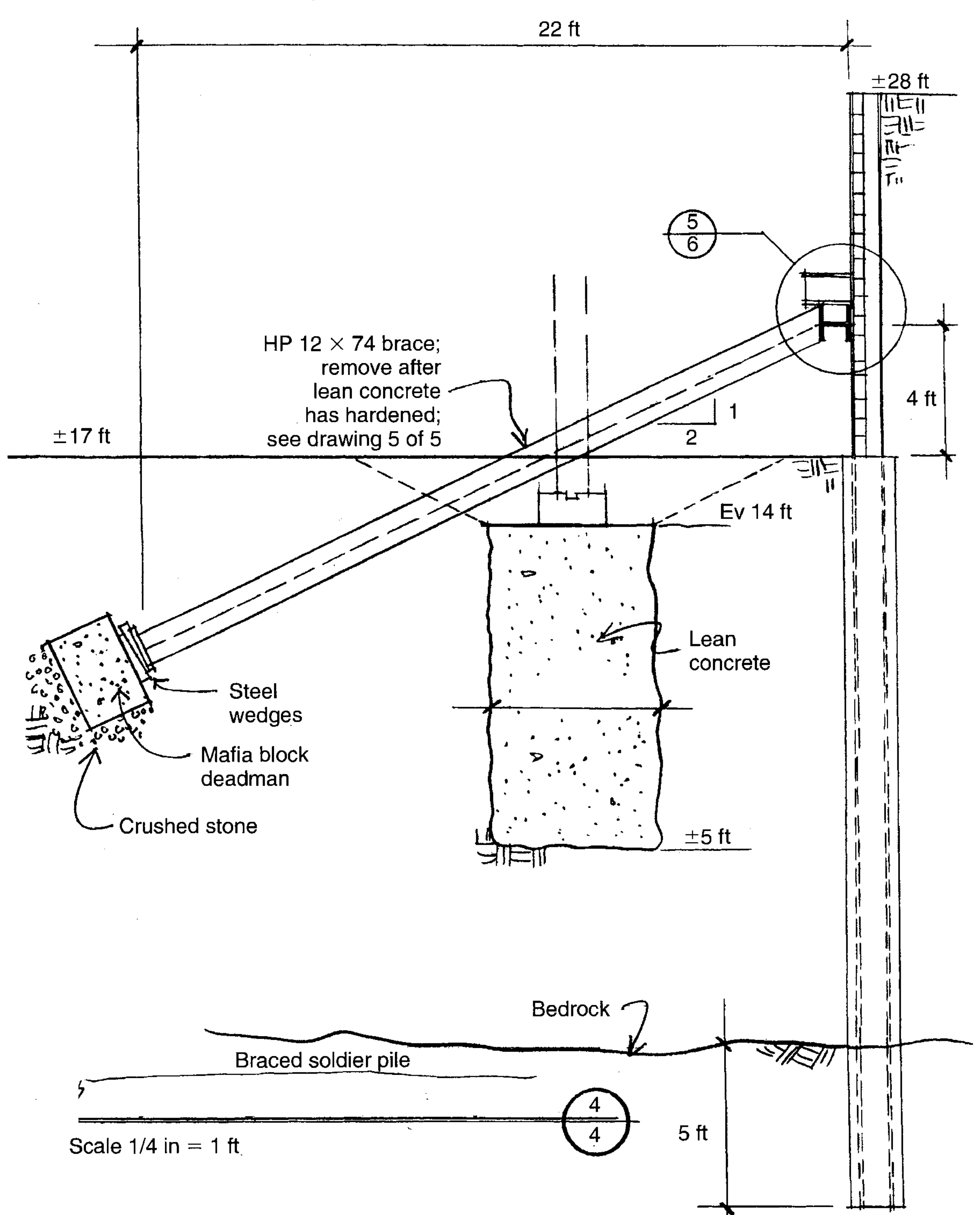


Bracing plan
Scale 1/4 = 1 ft

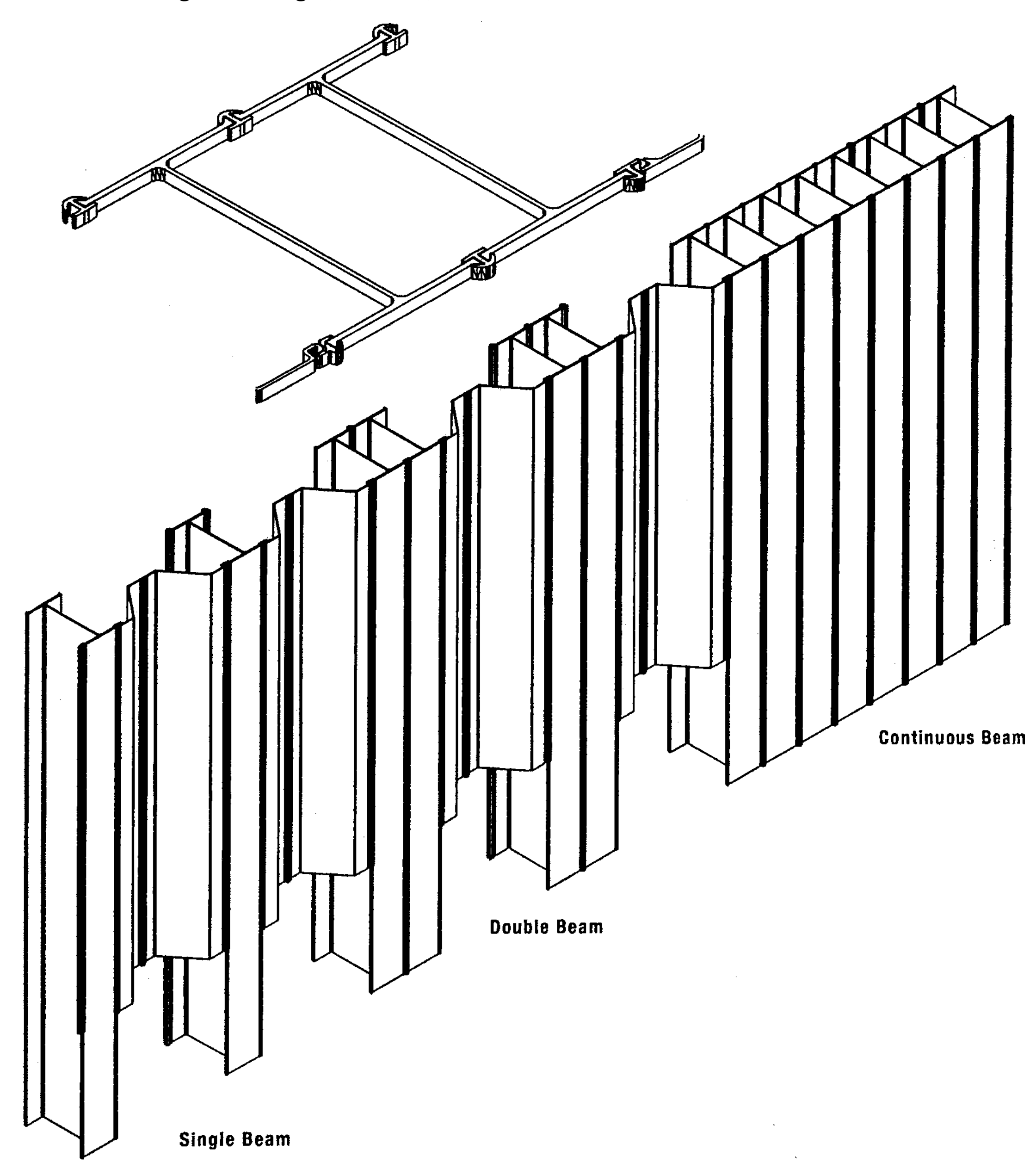


Waler detail
3/4 in = 1 ft

2.9.4 Typical Soldier Pile, Rock Bearing, with Mafia Block Deadman



2.10.0 Steel Sheet Piling with Single, Double, Continuous Beams



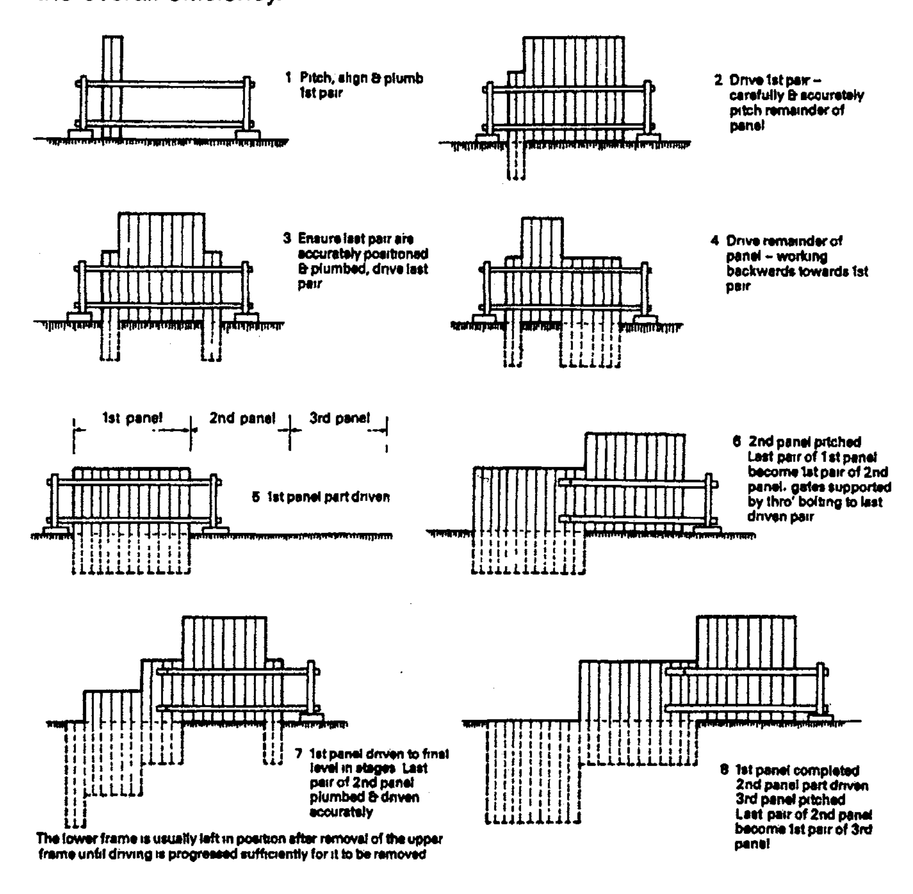
Source: Skyline Steel–Parsippany, New Jersey.

2.10.1 Panel Driving

Sheet piles should be installed using the panel-driving technique in order to ensure that good verticality and alignment is achieved and to minimize the risk of driving difficulties or de-clutching problems.

This technique also enables greater control to be maintained on the nominal wall length.

Because a whole panel of piles has been pitched there is no need to drive all piles fully to maintain piling operations; if obstructions are encountered, individual piles can be left high without fear of disruption to the overall efficiency.

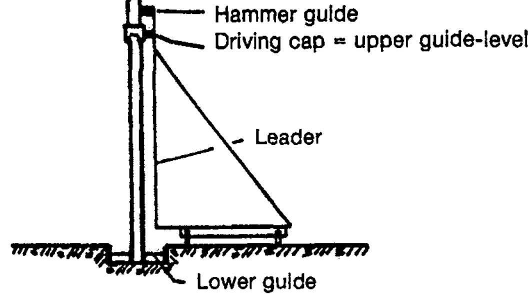


2.10.2 Pile Driving Guides

General

It is particularly important that sheet piles are maintained in the correct horizontal and vertical alignment during installation. This is achieved by the use of efficient pile guides, which will also prevent lateral drift.

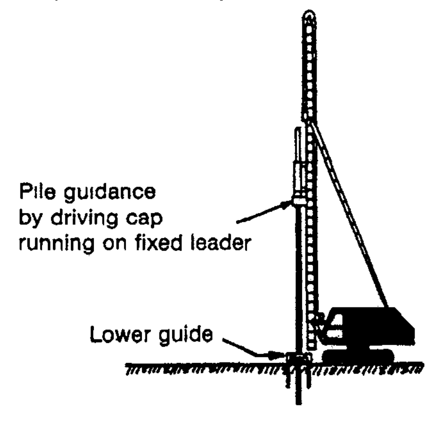
Each element to be driven must be guided in at least two levels. The accuracy and effectiveness of the guides will be improved by maximizing the distance between the two levels. Very long sheet piles may need intermediate guides to prevent flexing and other associated driving problems.



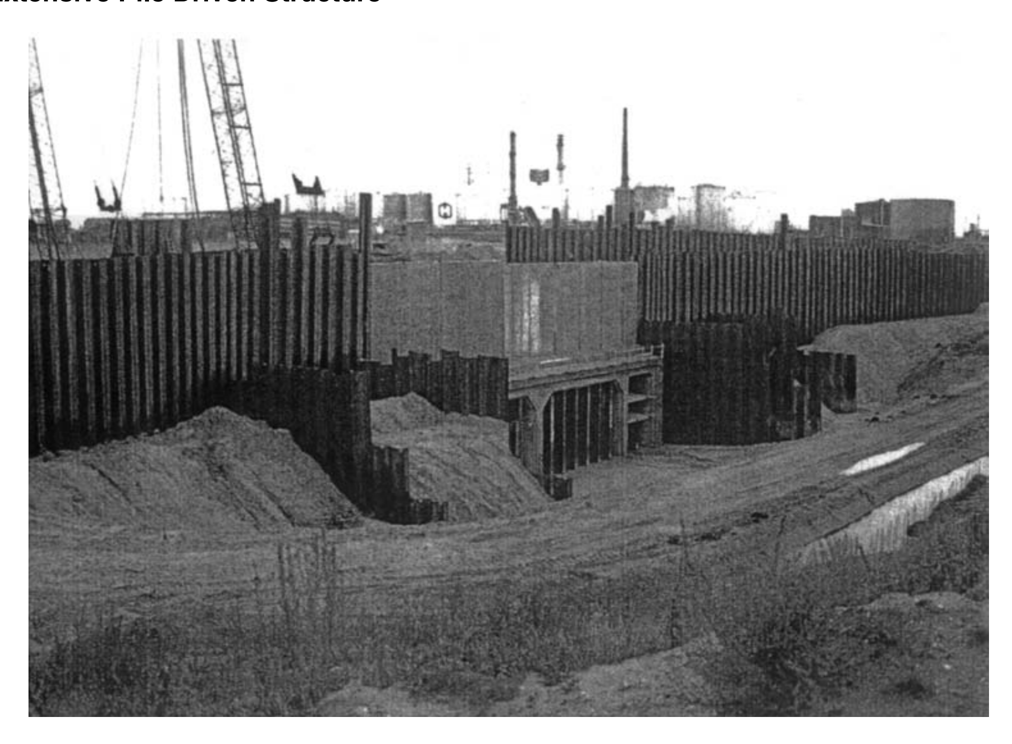
Upper guide

Driving with fixed leader

With this method both the hammer and the pile are guided by the leader. It is therefore important that the fixed leader is always vertical and that the hammer impacts its energy down the centroid of the pile profile.



2.10.3 Extensive Pile Driven Structure



2.11.0 Caissons

A caisson is a watertight retaining structure employed when work is required in a waterway or construction of a dam. Shallow caissons are open to the atmosphere and may have internal dewatering devices if water seepage is to be kept to a minimum. Excavate is removed by a crane on shore or mounted on a barge. When deep caissons are employed, say, for bridge foundations, they are often sealed and slightly pressurized to keep out oozing mud and water. Workers will enter this space via an air lock, and all muck, rock, and other debris will be removed through a tube where a surface-mounted crane with a bucket or clamshell will bring this material out of the excavated area.

2.11.1 Box Caissons

A prefabricated concrete box with four sides and a bottom set in place on a prepared base is a box caisson. When this “form” has been set in place, it will be filled with concrete to serve as a foundation, often used for bridge structures.

2.11.2 Open Caisson

An open caisson is similar to a box caisson except that it does not have a bottom. It is used where trench excavations are impractical and there is a need to install a manhole pump station or similar structure in an area of soft clays or high water tables.

2.12.0 Cofferdams

A cofferdam is a temporary structure constructed of steel sheet piling of interlocking panels to form a relatively watertight structure surrounding an area where new construction or repair of an existing structure is to take place. Cofferdams can be square, rectangular, or round.

2.13.0 Slurry Walls

A slurry wall is a nonstructural wall constructed when working in an underground environment that requires a method to impede groundwater flow. Slurry wall construction exerts hydraulic pressure

against a deep trench wall that is kept full with an engineered mixture—slurry. This temporary measure acts as temporary shoring to prevent collapse of the excavate walls. Bentonite is the most common material used in a slurry wall trench work. This bentonite material of clay mixed with water forms a colloidal mix that is pumped into the narrow trench, forming the slurry wall.

2.14.0 Soil Nailing



Soil nailing is an economical technique for stabilizing slopes and for constructing retaining walls from the top down. This ground reinforcement process uses steel tendons which are drilled and grouted into the soil to create a composite mass similar to a gravity wall. A shotcrete facing is typically applied, though many architectural options such as precast panels or “green” vegetated cells are available for permanent wall facings.

By permission, Rembco Geotechnical Contractors, Knoxville, TN.

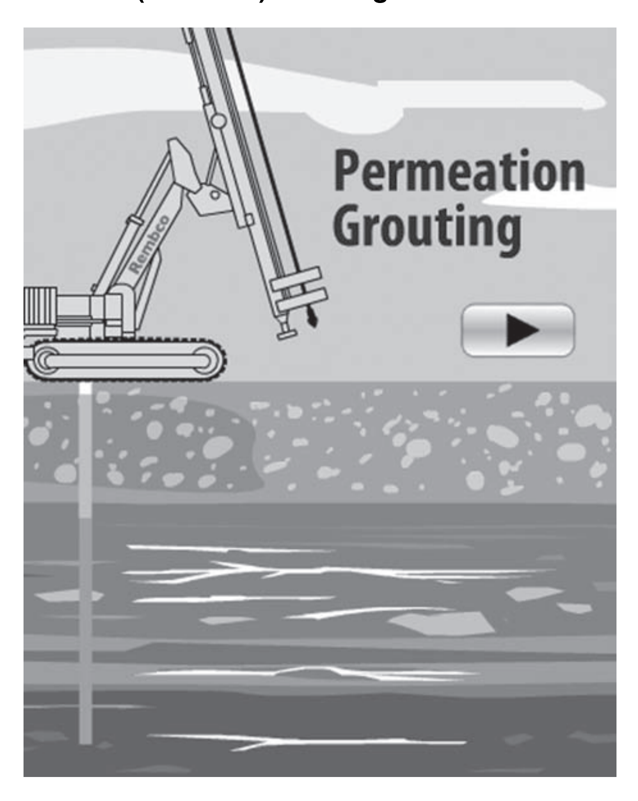
2.15.0 Earth and Rock Anchors



Earth or rock anchors generally consist of steel elements (bars or strands) grouted in a drilled hole. The bars or strands are subsequently tensioned. This provides lateral or vertical force to resist movement of a retaining structure. Anchors are often used for excavation support, or as a part of permanent retaining walls, or to resist up-lift forces on foundations. Rembco uses rock anchors to stabilize slopes and walls, provide tiebacks for bridges, stabilize dams, and secure caisson bottoms.

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2.16.0 Permeation (Pressure) Grouting



The term **"Pressure Grouting"** is in widespread use, but it is frequently misused. Although it seems to describe a specific type of grouting, the term is not specific. It refers to a wide variety of procedures. All grouting is done under pressure, so it is kind of like saying, "wet water". **Permeation Grouting** is a more precise term for what is commonly referred to as pressure grouting.

Permeation grouting is the direct pressure injection of a fluid grout into the ground to fill the spaces between particles. It is a very flexible approach to ground improvement.

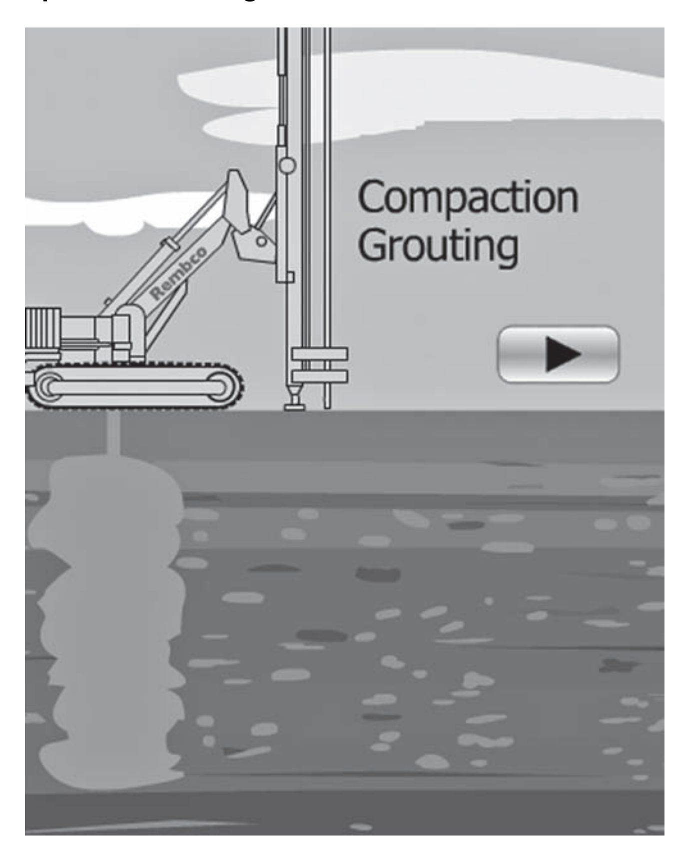
Injection methods are tailored specifically to a project. Some jobs are well suited to drill rigs and high-rate batch plants; other jobs are better suited to hand drills and small metering pumps. Sleeve-port pipes and downhole packers are often used to isolate particular zones in a formation. The choice of materials offers hundreds of options, ranging from cement slurries to specially designed chemical solutions.

All these options provide a project designer with a wide range of alternatives. Any effective grouting program requires a thorough evaluation of these options. The challenge is to find the best combination of methods and materials to achieve all technical objectives, while accommodating other factors such as existing ground properties, cost, and accessibility.

An effective grout program also requires a contractor with technical expertise to implement the project. Rembco has been designing and performing permeation grouting programs for more than 25 years. Rembco uses pressure grout methods for preventing water flow, stabilizing granular material, encapsulating contaminated material, and improving the physical properties of soil or rock. We have also effectively used permeation methods to fill voids, cracks, fractures, cavities, and to create barriers to the movement of liquids through the ground.

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2.17.0 Compaction Grouting



Compaction Grouting uses controlled displacement to increase the density of soft or loose soils. It is typically used for settlement control, structural re-leveling, and remediation of sinkholes. A small diameter (2" – 4") steel casing is advanced through the zone to be improved, and a stiff mortar-like grout is injected at high pressure to displace and compact and the surrounding soils. Pumping is continued as the grout casing is withdrawn, forming a larger diameter (12" – 18") column of interconnected grout bulbs. As they form, they intensely compact the soil around them. Compaction *piles* can be formed in the same manner to create a continuous structural support for foundations.

Due to relatively small injection pressure ports, compaction grouting can be performed with minimal disruption to building-use, without interference to other existing construction programs.

In our 25 years of geotechnical specialty work, Rembco has used compaction grouting to improve the ground beneath settling structures, provide excavation support, block the flow-path of viscous liquids, fill rock cracks, construct underpinning, densify footing soils, remediate threatening sinkholes, and re-level roads, bridges, towers and existing structures.

By permission, Rembco Geotechnical Contractors, Knoxville, TN.

2.18.0 Chemical Grouting

Chemical Grouting is a form of permeation grouting. Solution grouts that are commonly used include acrylamides, polyurethanes, acrylates, epoxies and sodium silicates. There are two major types of chemical grouting: structural and water control.

Structural chemical grouting, when used in granular soils, permeates the spaces between the soil particles, binds the particles together, and improves the soil's bearing capacity. This process is not necessarily intended to restrict water from moving through the soil.

Structural grouting is also used to repair fractures in concrete and rock. When injected into the cracks, the solution grout fills gaps with a powerful adhesive, forms a waterproof bond, repairs the integrity of a rock or concrete structure, and could be the least expensive means to seal joints and fractures.

Water control chemical grout is frequently used to stop water movement in granular soil or rock. Grout is injected under pressure and fills the spaces between soil particles. This forms a waterproof mass at the injection point. When injection points are laid-out in a well designed grid pattern, these masses interconnect to form an underground curtain that prevents fluid migration.

Water control chemical grouting is also widely used as an economical means to stop leaks in mines, tunnels, underground tanks, elevator shafts, and around underground conduits and pipes. Holes are drilled and grout is injected along the flow paths, sealing flow paths and preventing water flow through them. The work may be conducted from either the interior or exterior of a structure, depending on access restrictions.

2.19.0 Soil Mixing

This is a process whereby the physical and chemical characteristics of the soil can be changed without excavation. Often the intent of most soil mixing is to create properties similar to those of lightly cemented sandstone or soft rock. Soil mixing is often used as a stabilizer when pit shoring is required .and can be an alternate to or combined with beam and wood lagging, soldier piles, sheet piling, or jet grouting walls. Soil mixing is also used to consolidate contaminated materials in the soil.

Deep soil mixing is accomplished by installing a series of overlapping stabilized soil columns generally 24 in. (61 cm) to 56 in. (142 cm) in diameter and 40 ft (12 m) or more in depth. Crane-supported mixing shafts are guided by the crane's leads, and as the shaft is drilled into the soil, grout or slurry is pumped through the hollow stem of the mixing shaft and injected into the soil. The augers with paddles are slowly rotated into the grade at about 10 to 20 rpm, and these mixing blades within the shafts blend the grout or slurry into the soil. Since fluid is introduced into the soil, some spoils will surface.

Other methods of mixing a cement-type slurry with soil consists of jet grouting where high-pressure cement slurry is pumped through horizontal ports in a drill casing above the drill bit. The high velocity and the pressure of the slurry cut and mix with the soil.

Soil mixing is vibration-free and generates very little noise.

2.20.0 Tunnel Boring Machines (TBMs)

As public transportation systems and other infrastructure demands grow in our changing urban environment, new subway systems are being constructed and existing ones expanded, and aging underground utilities are being replaced or upgraded. Open cut is not an option, and various types and sizes of tunnel boring machines (TBMs) are employed to build subways and remediate underground water, sewer, and sanitary lines. From microtunneling machines with 6-in.- (15-cm-) diameter to giant 49-ft- (15.3-m-) diameter giant TBMs, more cities and regions around the world now rely on tunnel system excavation to satisfy their increasing urban needs.



By permission, Herrenknecht, Allmannsweier, Germany.

2.20.1 A Glossary of Tunneling Terms

Annulus The cavity between the outside of the pipeline and the overcut of the TBM cutting head.

AVN A remotely controlled tunneling machine incorporating slurry removal.

Bentonite An expansive clay used in the slurry material, acting as a support for the tunnel face. Also serves as a pipeline lubricant.

Blind hole A tunnel that ends as a "blind alley."

Bucket tooth An excavation tool in the form of a toothlike device mounted on the bucket and used for partial face excavation.

Compressed air lock A chamber to transfer persons or materials inside and outside, from the outside atmospheric environment to the pressurized environment of a tunnel.

Cone crusher The cone-shaped part of the TBM located behind the cutter head to crush large stones so they can be more easily removed from the tunnel.

Control stand The workstation for the machine operator, either directly inside the machine or at a remote location.

Cutter head The rotating head of the TBM

Disks The rotating tools equipped with hardened cutter rings for a hard rock tunneling machine.

Earth pressure balance (EPB) shield The earth and/or water pressure at the tunnel face compensated by the excavation chamber which is filled with plastic soil.

Full-face tunneling machine The excavating machine that removes the material at the whole tunnel face with the help of a rotating cutter head.

Geothermy Use of the natural heat of the earth to generate electricity or for power-heat coupling.

Horizontal directional drilling (HDD) Method used to install gas and oil pipelines using an HDD drilling rig.

In-situ casting Transferable formwork filled with concrete in situ (in place). Once the concrete hardens and the forms are removed, the shell becomes the finished shaft construction.

Intermediate jacking stations Cylindrical steel cans with integrated hydraulic jacking cylinders built into the pipeline at certain intervals to be put into operation when the permissible jacking force is reached at the main jacking station.

Muck pumping Technology to remove excavated material with muck (piston) pumps similar to concrete pumps.

Partial face excavation Excavation of the tunnel face part by part.

Reception shaft The form or pit where tunneling ends.

Roundhead Longitudinal cutter head mounted on a special boom for partial face excavation.

Segmental lining Individual precast concrete or steel segments assembled in the launch shaft to form complete rings for installation directly behind the TBM.

Separation plant The use of screens, cyclones, centrifuges, and sedimentation tanks to separate the excavated material from the slurry fluid.

Shaft lining Precast concrete segments complete the watertight final construction of the shaft during the shaft sinking process.

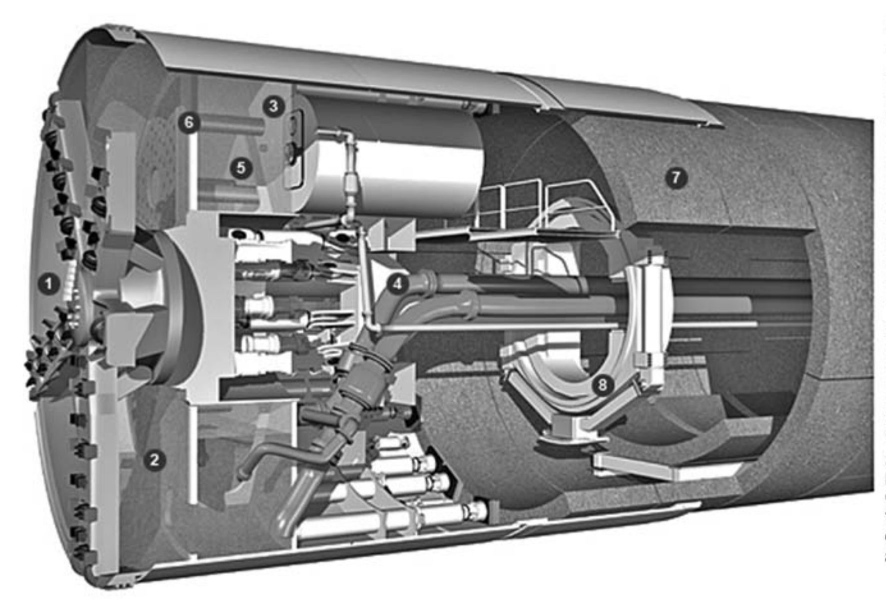
Shaft sinking unit Bore down shafts in a mechanized procedure.

Shield Exterior steel sleeve; the basic construction of a TBM serving as a protection against the surrounding earth and groundwater.

Utility tunneling machine Staffed or remote-controlled TBM with nominal diameters of up to 13.7 ft (4.2 m).

2.20.2 AVN Machine

AVN is a German acronym for Automatischer Vortrieb Nass (remote-controlled slurry tunneling machine). The slurry supports the tunnel face with a pressurized bentonite-water mix controlled by a compressed air cushion in the second compartment of the excavation chamber.

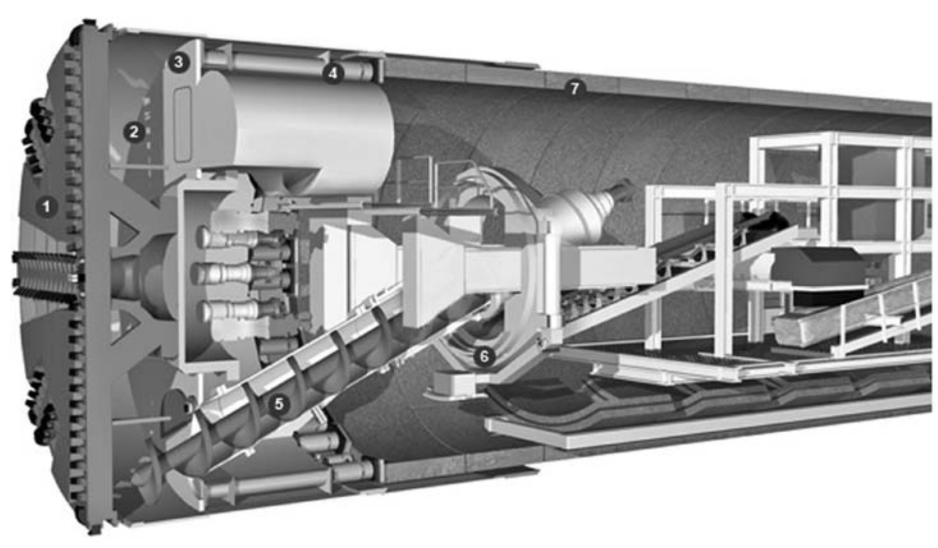


The tunnelling principle: Behind the cutting wheel ❶ with its scraper tools and cutter disks there is a steel tube, the shield ❷. It offers protection during tunnelling. The space in front of the pressure bulkhead ❸ is filled with bentonite suspension which supports the existing soil. The pressure required to support the tunnel face is controlled with a compressed air cushion ❹ in the excavation chamber, which is divided by a submerged wall ❺. The excavated soil is pumped away together with the suspension in the slurry line (green) ❻. Larger rocks are crushed by a stone crusher ❼. The removed suspension is replaced through the feed line (blue) ❽. Under the protection of the shield, lining segments ❾ made of reinforced concrete *are put in place by a lining segment erector* ❿. To bore forward, the machine pushes itself away from the last completed tunnel ring using hydraulic thrust cylinders ⓫.The annular space between the segment ring and the soil is filled continuously with mortar. All activities are monitored from the control cabin.

By permission, Herrenknecht, Allmannsweier, Germany.

2.20.3 Earth Pressure Balance Shield Tunneling Machine

This TBM is suitable for tunneling in soft ground. A line of reinforced concrete lining segments can be positioned directly behind the machine, and the EPB shield pushes itself off from the last installed segment ring.



Using EPB machines, the soil is excavated by the tools on the rotating cutting wheel ❶ at the tunnel face and passes through the openings in the cutting wheel into the excavation chamber ❷. There, it mixes with the other plastic soil. The force from the thrust cylinders ❹ is transmitted via the pressure bulkhead ❸ to the soil to support the tunnel face and control the entry of material into the excavation chamber. The excavated material is removed by the screw conveyor ❺ from the excavation chamber which is under pressure and into the tunnel which is under atmospheric pressure. With the help of an erector ❻ the tunnel lining segments ❼ are built directly behind the shield.

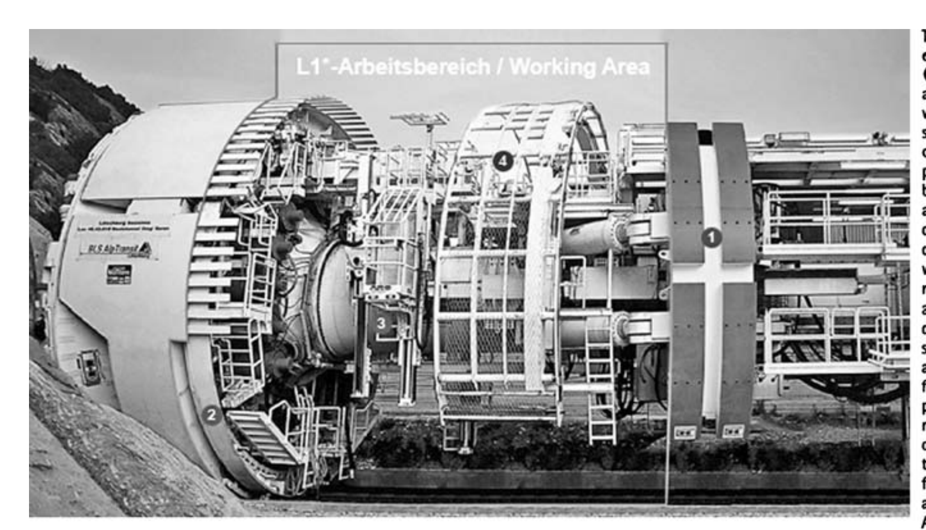
By permission, Herrenknecht, Allmannsweier, Germany.

2.20.4 Fluid Supported Mix Shield Tunneling Machine

This TBM is used in many types of projects including those with high water content. The tunnel is supported by a bentonite mixture, used in areas where high water permeability exists, including those with sand and gravel at the rear of the shield, the tail skin. The tunnel is then lined with reinforced concrete lining segments.

2.20.5 Gripper TBM (Both Single and Double)

This gripper TBM is used for hard rock boring. The TBM braces itself against the rock at the rear with two gripper plates. Hydraulic cylinders push the cutter head into the tunnel face where the rock is crushed by disk cutters, two cylinders in the single gripper, four hydraulically operated gripper plates in the double gripper.

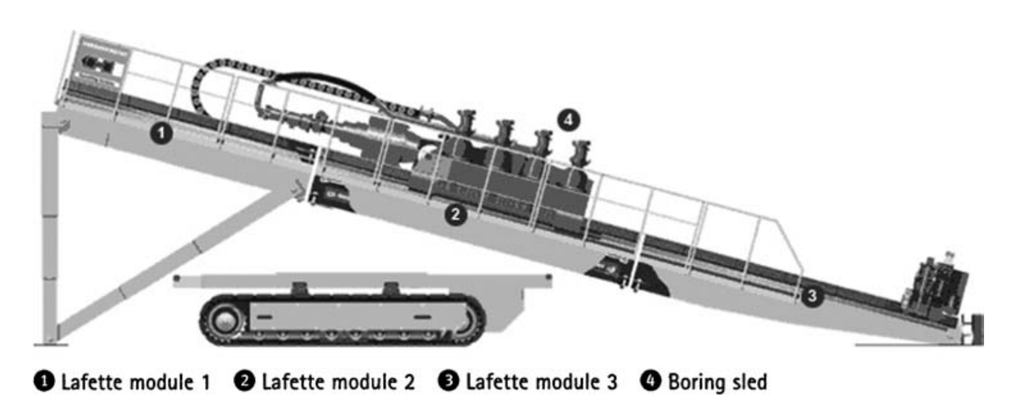


The Gripper TBM has a ring erector ❸ behind the shield ❶, which is used to pre-assemble arched segments within the protection of the short finger shield ❷. The complete ring is then transported to the installation site, braced against the rock face and assembled. Both independently maneuverable anchor drills ❹ are operated from work cages with protective roofs ❺. This means that anchors can be positioned directly behind the cutterhead shield. Mesh for protection against falling rocks or reinforcement steel mats are placed onto the moveable mesh erector unit ❻ in front of the gripper plates ❼ and then they are transported forward to the working area and anchored in the rock. All safety measures can be carried out independent of the boring operation.

By permission, Herrenknecht, Allmannsweier, Germany.

2.20.6 HDD Rig

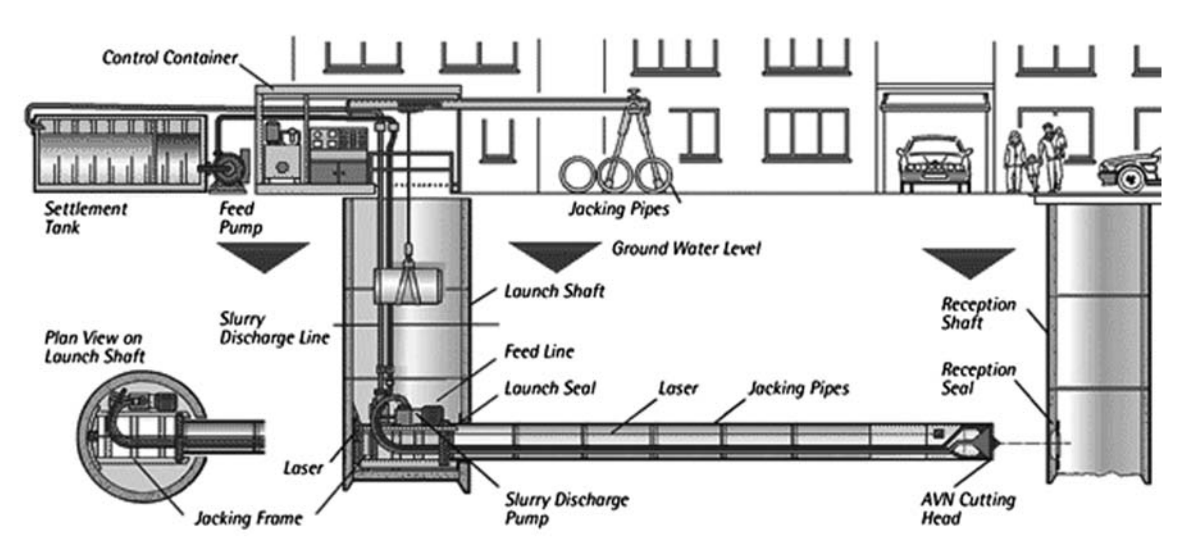
The HDD rig is used for small-diameter utility installations such as gas and oil pipelines.



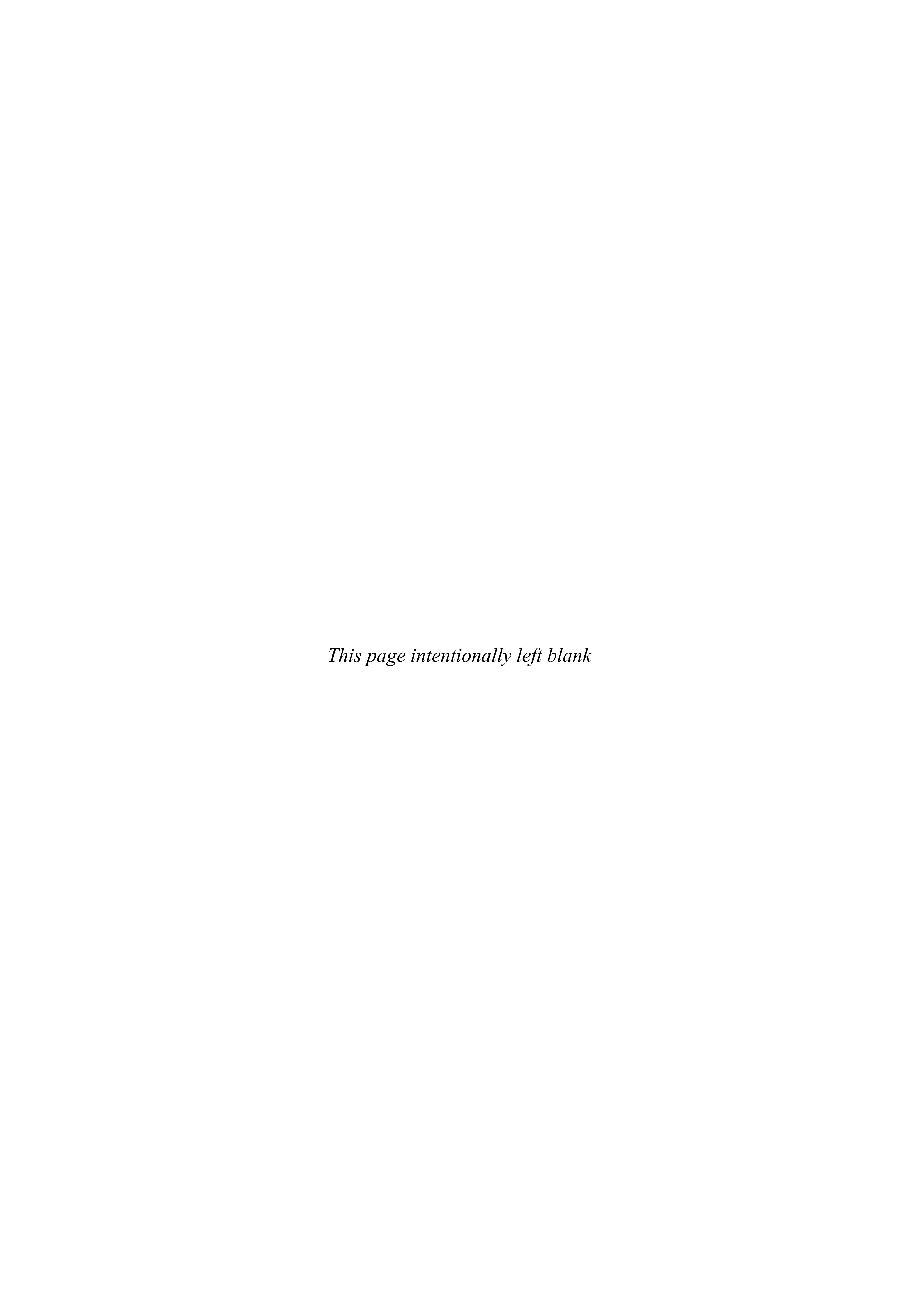
By permission, Herrenknecht, Allmannsweier, Germany.

2.20.7 Underground Small-Bore Utility Tunnels Lowered through a Shaft and Remotely Controlled

This is a method by which some underground small-bore utility tunnels are lowered through a shaft and remotely controlled.



By permission, Herrenknecht, Allmannsweier, Germany.



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Section

3

Building Envelope

Contents

3.0.0 Structural Steel

A basic component of construction, structural steel is categorized by specific steel shapes, cross sections, and chemical composition.

3.0.1 ASTM Designations for Most Commonly Used Structural Steel Members

ASTM Designation	Min. Yield Stress (ksi)	Min. Tensile Stress (ksi)
A36	36	58–60
A572 grade 50	50	65
A572 grade 60	60	75
A572 grade 65	65	80
A992	50–65	65

3.0.1.1 Alloy Steel Designation and Uses

- A36, structural shapes and plates
- A53, structural pipe and tubing
- A500, structural pipe and tubing
- A501, structural pipe and tubing
- A529, structural shapes and plate

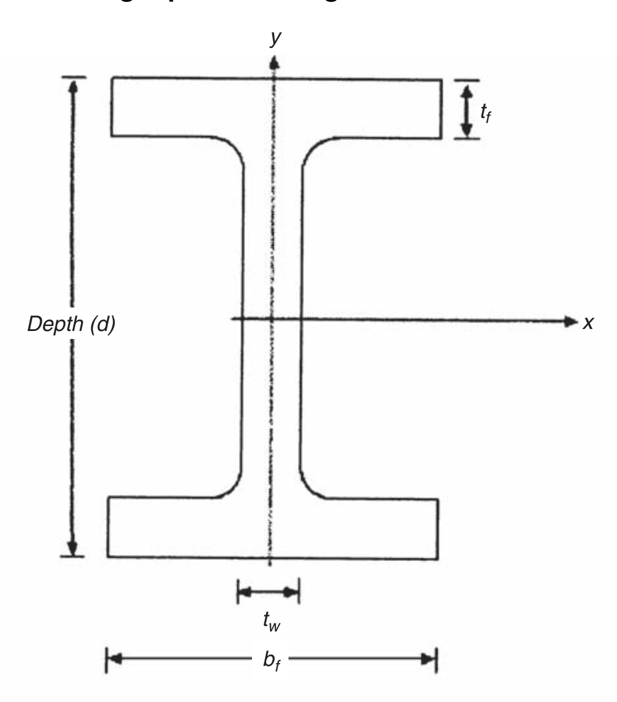
High-strength, low-alloy steel

- A441, structural shapes and plate
- A572, structural shapes and plate
- A618, structural piping and tubing
- A992, W shapes for beams
- A270, structural shapes and plate

Corrosion-resistant, high-strength low-alloy steel

- A242, structural shapes and plate
- A514, structural shapes and plate
- A517, boilers and pressure vessels
- A588, structural shapes and plate

3.1.0 Wide-Flange Beams—Depth and Weight per Unit Length



The I-Beams are identified by:
W DEPTH (inches) × WEIGHT PER UNIT LENGTH (pound force per foot)

For Example: **W27 × 161** is an I-Beam with a Depth of 27 inches and having a Nominal Weight of 161 lbf/ft.

W27 × ___	**W24 × ___**	**W21 × ___**	**W18 × ___**	**W16 × ___**
W27 × 178	W24 × 162	W21 × 147	W18 × 119	W16 × 100
W27 × 161	W24 × 146	W21 × 132	W18 × 106	W16 × 89
W27 × 146	W24 × 131	W21 × 122	W18 × 97	W16 × 77
W27 × 114	W24 × 117	W21 × 111	W18 × 86	W16 × 67
W27 × 102	W24 × 104	W21 × 101	W18 × 76	W16 × 57
W27 × 94	W24 × 94	W21 × 93	W18 × 71	W16 × 50
W27 × 84	W24 × 84	W21 × 83	W18 × 65	W16 × 45
	W24 × 76	W21 × 73	W18 × 60	W16 × 40
	W24 × 68	W21 × 68	W18 × 55	W16 × 36
	W24 × 62	W21 × 62	W18 × 50	W16 × 31
	W24 × 55	W21 × 57	W18 × 46	W16 × 26
		W21 × 50	W18 × 40	
		W21 × 44	W18 × 35	

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3.1.0 Wide-Flange Beams—Depth and Weight per Unit Length (Continued)

W14 × ___

- W14 × 665
- W14 × 605
- W14 × 550
- W14 × 500
- W14 × 455
- W14 × 426
- W14 × 398
- W14 × 370
- W14 × 342
- W14 × 311
- W14 × 283
- W14 × 257
- W14 × 233
- W14 × 211
- W14 × 193
- W14 × 176
- W14 × 159
- W14 × 145
- W14 × I32
- W14 × 120
- W14 × 109
- W14 × 99
- W14 × 90
- W14 × 82
- W14 × 74
- W14 × 68
- W14 × 61
- W14 × 53
- W14 × 48
- W14 × 43
- W14 × 38
- W14 × 34
- W14 × 30
- W14 × 26
- W14 × 22

W12 × ___

- W12 × 336
- W12 × 305
- W12 × 279
- W12 × 252
- W12 × 230
- W12 × 210
- W12 × 190
- W12 × 170
- W12 × 152
- W12 × 136
- W12 × 120
- W12 × 106
- W12 × 96
- W12 × 87
- W12 × 79
- W12 × 72
- W12 × 65
- W12 × 58
- W12 × 53
- W12 × 50
- W12 × 45
- W12 × 40
- W12 × 35
- W12 × 30
- W12 × 26
- W12 × 22
- W12 × 19
- W12 × 16
- W12 × 14

W10 × ___

- W10 × 112
- W10 × 100
- W10 × 88
- W10 × 77
- W10 × 68
- W10 × 60
- W10 × 54
- W10 × 49
- W10 × 45
- W10 × 39
- W10 × 33
- W10 × 30
- W10 × 26
- W10 × 22
- W10 × 19
- W10 × 17
- W10 × 15
- W10 × 12

W8 × ___

- W8 × 67
- W8 × 58
- W8 × 48
- W8 × 40
- W8 × 35
- W8 × 31
- W8 × 28
- W8 × 24
- W8 × 21
- W8 × 18
- W8 × 15
- W8 × 13
- W8 × 10

W6 × ___

- W6 × 20
- W6 × 16
- W6 × 15
- W6 × 12
- W6 × 9

W5 × ___

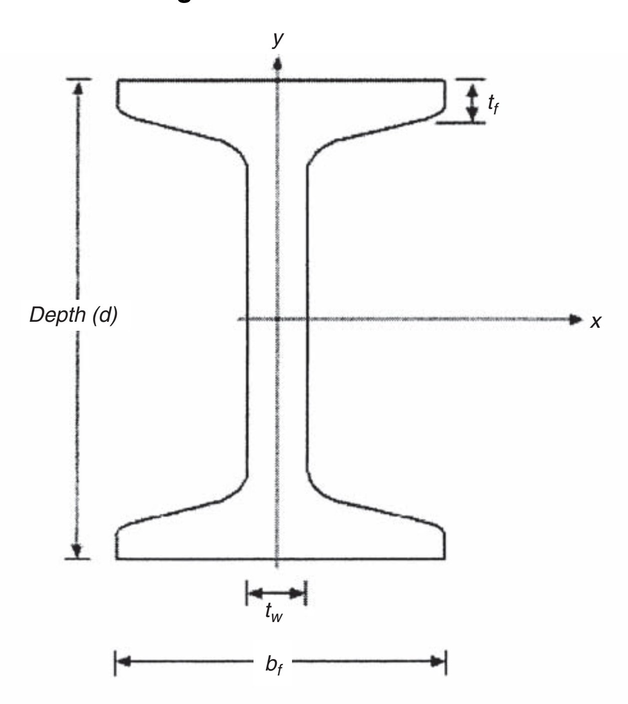
- W5 × 19
- W5 × 16

W4 × ___

- W4 × 13

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3.1.1 I Beam Depth and Weight per Unit of Length



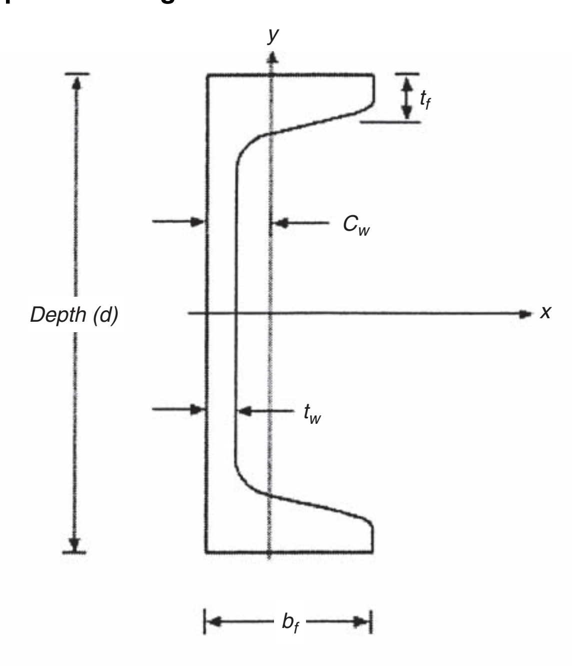
The I-Beams are identified by:
S DEPTH (inches) × WEIGHT PER UNIT LENGTH (pound force per foot)

For Example: **S18 × 54.7** is an I-Beam with a Depth of 18 inches and having a Nominal Weight of 54.7 lbf/ft.

S24 × ____	**S20 × ____**	**S18 × ____**	**S15 × ____**	**S12 × ____**
S24 × 121	S20 × 96	S18 × 70	S15 × 50	S12 × 50
S24 × 106	S20 × 86	S18 × 54.7	S15 × 42.9	S12 × 40.8
S24 × 100	S20 × 75			S12 × 35
S24 × 90	S20 × 66			S12 × 31.8
S24 × 80				
S10 × ____	**S8 × ____**	**S7 × ____**	**S6 × ____**	**S5 × ____**
S10 × 35	S8 × 23	S7 × 20	S6 × 17.25	S5 × 14.75
S10 × 25.4	S8 × 18.4	S7 × 15.3	S6 × 12.5	S5 × 10
S4 × ____	**S3 × ____**			
S4 × 9.5	S3 × 7.5			
S4 × 7.7	S3 × 5.7			

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3.1.2 C Channel Depth and Weight per Unit Length

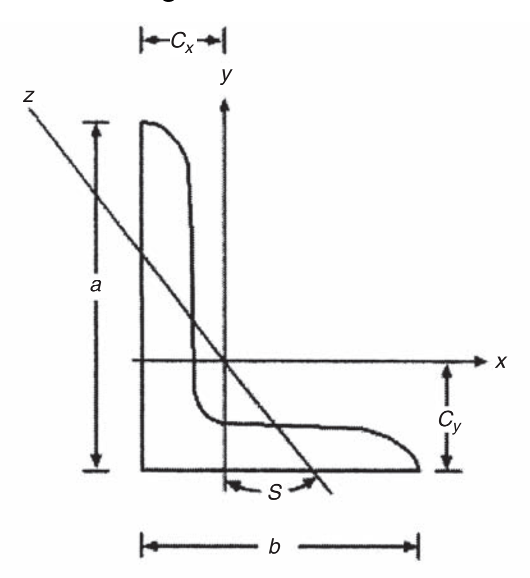


The Channels are identified by:
C DEPTH (inches) × WEIGHT PER UNIT LENGTH (pound force per foot)
For Example: **C12 × 30** is a Channel with a Depth of 12 inches and having a Nominal Weight of 30 lbf/ft.

C15 × ____	**C12 × ____**	**C10 × ____**	**C9 × ____**	**C8 × ____**
C15 × 50	C12 × 30	C10 × 30	C9 × 20	C8 × 13.75
C15 × 40	C12 × 25	C10 × 25	C9 × 15	C8 × 11.5
C15 × 33.9	C12 × 20.7	C10 × 20	C9 × 13.4	
		C10 × 15.3		
C7 × ____	**C6 × ____**	**C5 × ____**	**C4 × ____**	**C3 × ____**
C7 × 14.75	C6 × 13	C5 × 9	C4 × 7.25	C3 × 6
C7 × 12.25	C6 × 10.5	C5 × 6.7	C4 × 5.4	C3 × 5
C7 × 9.8	C6 × 8.2			C3 × 4.1

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3.1.3 Steel Angles—Length and Thickness of Leg in Inches



The Angles are identified by:
LLEG$_a$ inches×LEG$_b$ inches×THICKNESS inches

For Example: **L4×3×5/8** is an Angle with one 4 inch leg one 3 inch leg and having a thickness of 5/8 of an inch.

L8×8×__	**L6×6×__**	**L5×5×__**	**L4×4×__**
L8×8×1 1/8	L6×6×1	L5×5×7/8	L4×4×3/4
L8×8×1	L6×6×7/8	L5×5×3/4	L4×4×5/8
L8×8×7/8	L6×6×3/4	L5×5×5/8	L4×4×1/2
L8×8×3/4	L6×6×5/8	L5×5×1/2	L4×4×7/16
L8×8×5/8	L6×6×9/16	L5×5×7/16	L4×4×3/8
L8×8×9/16	L6×6×1/2	L5×5×3/8	L4×4×5/16
L8×8×1/2	L6×6×7/16	L5×5×5/16	L4×4×1/4
	L6×6×3/8		
	L6×6×5/16		

L3 1/2×3 1/2×__	**L3×3×__**	**L2 1/2×2 1/2×__**	**L2×2×__**
L3 1/2×3 1/2×1/2	L3×3×1/2	L2 1/2×2 1/2×1/2	L2×2×3/8
L3 1/2×3 1/2×7/16	L3×3×7/16	L2 1/2×2 1/2×3/8	L2×2×5/16
L3 1/2×3 1/2×3/8	L3×3×3/8	L2 1/2×2 1/2×5/16	L2×2×1/4
L3 1/2×3 1/2×5/16	L3×3×5/16	L2 1/2×2 1/2×1/4	L2×2×3/16
L3 1/2×3 1/2×1/4	L3×3×1/4	L2 1/2×2 1/2×3/16	L2×2×1/8
	L3×3×3/16		

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3.1.3 Steel Angles—Length and Thickness of Leg in Inches (Continued)

L9×4×__	L8×6×__	L8×4×__	L7×4×__
L9×4×5/8	L8×6×1	L8×4×1	L7×4×3/4
L9×4×9/16	L8×6×7/8	L8×4×3/4	L7×4×5/8
L9×4×1/2	L8×6×3/4	L8×4×9/16	L7×4×1/2
	L8×6×5/8	L8×4×1/2	L7×4×3/8
	L8×6×9/16		
	L8×6×1/2		
	L8×6×7/16		

L6×4×__	L6×3 1/2×__	L5×3 1/2×__	L5×3×__
L6×4×7/8	L6×3 1/2×1/2	L5×3 1/2×5/8	L5×3×5/8
L6×4×3/4	L6×3 1/2×3/8	L5×3 1/2×1/2	L5×3×1/2
L6×4×5/8	L6×3 1/2×5/16	L5×3 1/2×7/16	L5×3×7/16
L6×4×9/16		L5×3 1/2×3/8	L5×3×3/8
L6×4×1/2		L5×3 1/2×5/16	L5×3×5/16
L6×4×7/16		L5×3 1/2×1/4	L5×3×1/4
L6×4×3/8			
L6×4×5/16			

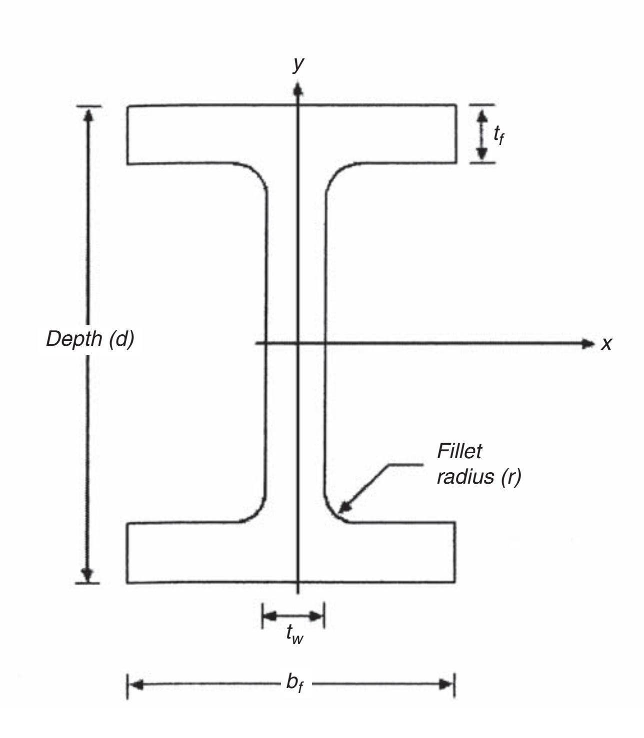
L4×3 1/2×__	L4×3×__	L3 1/2×3×__	L3 1/2×2 1/2×__
L4×3 1/2×1/2	L4×3×5/8	L3 1/2×3×1/2	L3 1/2×2 1/2×1/2
L4×3 1/2×7/16	L4×3×1/2	L3 1/2×3×7/16	L3 1/2×2 1/2×7/16
L4×3 1/2×3/8	L4×3×7/16	L3 1/2×3×3/8	L3 1/2×2 1/2×3/8
L4×3 1/2×5/16	L4×3×3/8	L3 1/2×3×5/16	L3 1/2×2 1/2×5/16
L4×3 1/2×1/4	L4×3×5/16	L3 1/2×3×1/4	L3 1/2×2 1/2×1/4
	L4×3×1/4		

L3×2 1/2×__	L3×2×__	L2 1/2×2×__
L3×2 1/2×1/2	L3×2×1/2	L2 1/2×2×3/8
L3×2 1/2×7/16	L3×2×7/16	L2 1/2×2×5/16
L3×2 1/2×3/8	L3×2×3/8	L2 1/2×2×1/4
L3×2 1/2×5/16	L3×2×5/16	L2 1/2×2×3/16
L3×2 1/2×1/4	L3×2×1/4	
L3×2 1/2×3/16	L3×2×3/16	

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3.1.4 Aluminum Beams and Channels

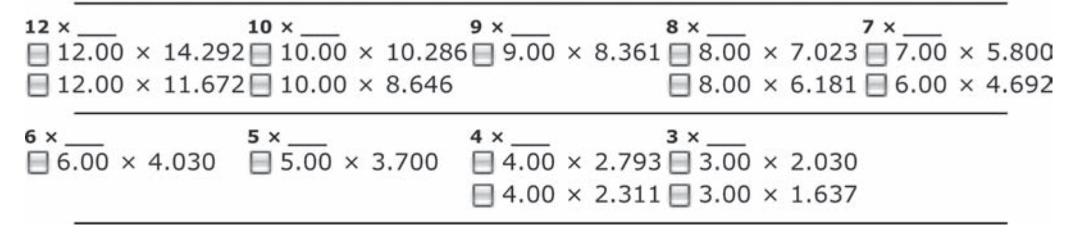
Aluminum I-Beams



The I-Beams are identified by:

DEPTH (inches) × WEIGHT PER UNIT LENGTH (pound force per foot)

For Example: **12 × 14.292** is an I-Beam 12 inches deep and weighing 14.292 lbs/ft.



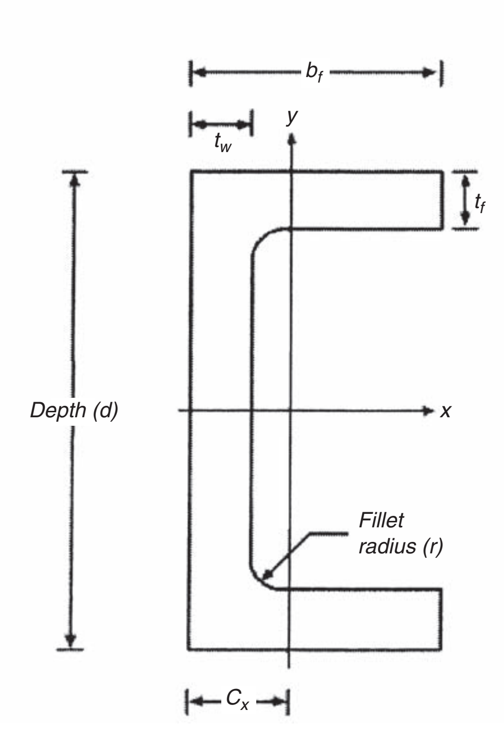
12 × ___	10 × ___	9 × ___	8 × ___	7 × ___
12.00 × 14.292	10.00 × 10.286	9.00 × 8.361	8.00 × 7.023	7.00 × 5.800
12.00 × 11.672	10.00 × 8.646		8.00 × 6.181	6.00 × 4.692

6 × ___	5 × ___	4 × ___	3 × ___
6.00 × 4.030	5.00 × 3.700	4.00 × 2.793	3.00 × 2.030
		4.00 × 2.311	3.00 × 1.637

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3.1.4 Aluminum Beams and Channels (Continued)

Aluminum Channels



The Channels are identified by:

DEPTH (inches) × WEIGHT PER UNIT LENGTH (pound force per foot)

For Example: **12 × 11.822** is an I-Beam 12 inches deep and weighing 11.822 lbs/ft.

12 × ___	10 × ___	9 × ___	8 × ___	7 × ___
12 × 11.822	10 × 8.36	9 × 6.97	8 × 5.789	7 × 4.715
12 × 8.274	10 × 6.136	9 × 4.983	8 × 4.147	7 × 3.205
6 × ___	**5 × ___**	**4 × ___**	**3 × ___**	**2 × ___**
6 × 4.03	5 × 3.089	4 × 2.331	3 × 1.597	2 × 1.071
6 × 2.834	5 × 2.212	4 × 1.738	3 × 1.135	2 × 0.577

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3.2.0 Open Web Joists, Standard and Nonstandard

ACCESSORIES AND DETAILS

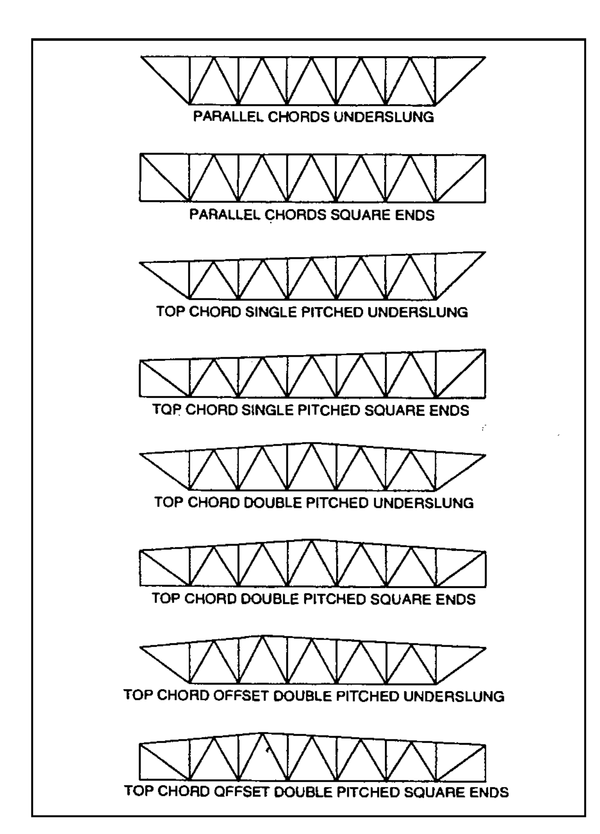
LH & **DLH** SERIES LONGSPAN STEEL JOISTS

STANDARD TYPES

Longspan steel joists can be furnished with either underslung or square ends, with parallel chords or with single or double pitched top chords to provide sufficient slope for roof drainage.

The Longspan joist designation is determined by its nominal depth at the center of the span, except for offset double pitched joists, where the depth should be given at the ridge. A part of the designation should be either the section number or the total design load over the design live load (TL/LL given in plf).

All pitched joists will be cambered in addition to the pitch unless specified otherwise.



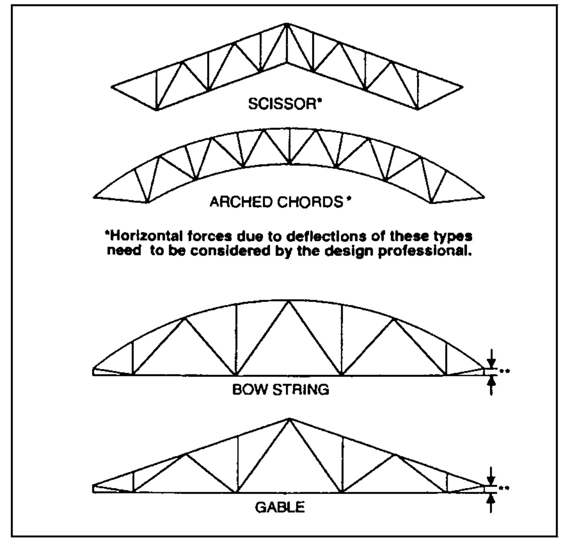
CAMBER

Non-Standard Types: The design professional shall provide on the structural drawings the amount of camber desired in inches. If camber is not specified, Vulcraft will use the camber values for LH and DLH joists based on top chord length.

Standard Types: The camber listed in the table will be fabricated into the joists unless the design professional specifically states otherwise on the structural drawings.

NON-STANDARD TYPES

The following joists can also be supplied by Vulcraft, however, **THE DISTRICT SALES OFFICE OR MANUFACTURING FACILITY NEAREST YOU SHOULD BE CONTACTED FOR ANY LIMITATIONS IN DEPTH OR LENGTH.**



**Contact Vulcraft for minimum depth at ends.

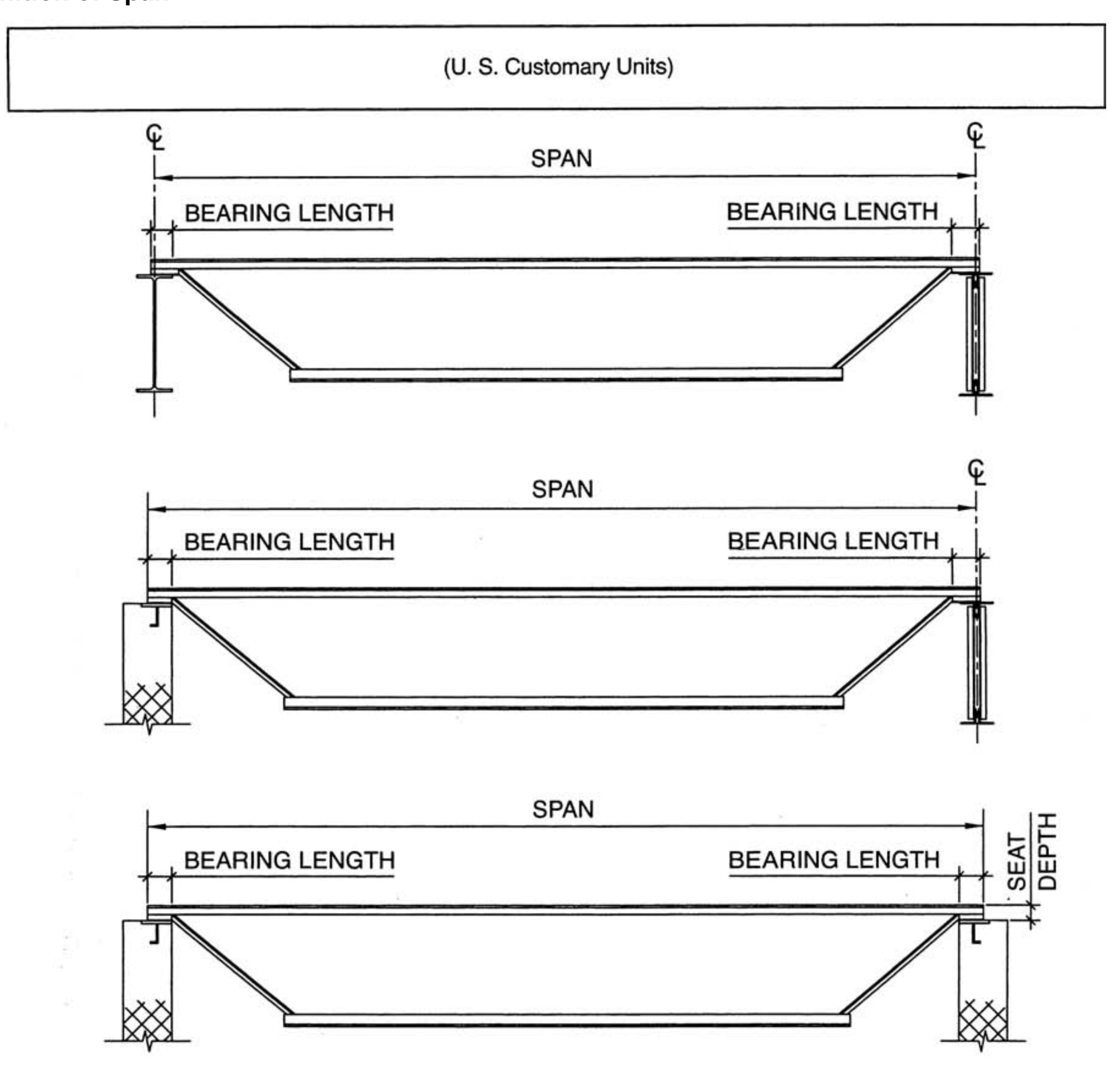
CAMBER FOR STANDARD TYPES

LH &DLH series joists shall have camber in accordance with the following table:***

Top Chord Length		Approx. Camber	
20'-0"	(6096 mm)	1/4"	(6 mm)
30'-0"	(9144 mm)	3/8"	(10 mm)
40'-0"	(12192 mm)	5/8"	(16 mm)
50'-0"	(15240 mm)	1"	(25 mm)
60'-0"	(18288 mm)	1 1/2"	(38 mm)
70'-0"	(21336 mm)	2"	(51 mm)
80'-0"	(24384 mm)	2 3/4"	(70 mm)
90'-0"	(27432 mm)	3 1/2"	(89 mm)
100'-0"	(30480 mm)	4 1/4"	(108 mm)
110'-0"	(33528 mm)	5"	(127 mm)
120'-0"	(36576 mm)	6"	(152 mm)
130'-0"	(39621 mm)	7"	(178 mm)
140'-0"	(42672 mm)	8"	(203 mm)
144'-0"	(43890 mm)	8 1/2"	(216 mm)

*** NOTE: If full camber is not desired near walls or other structural members please note on the structural drawings.

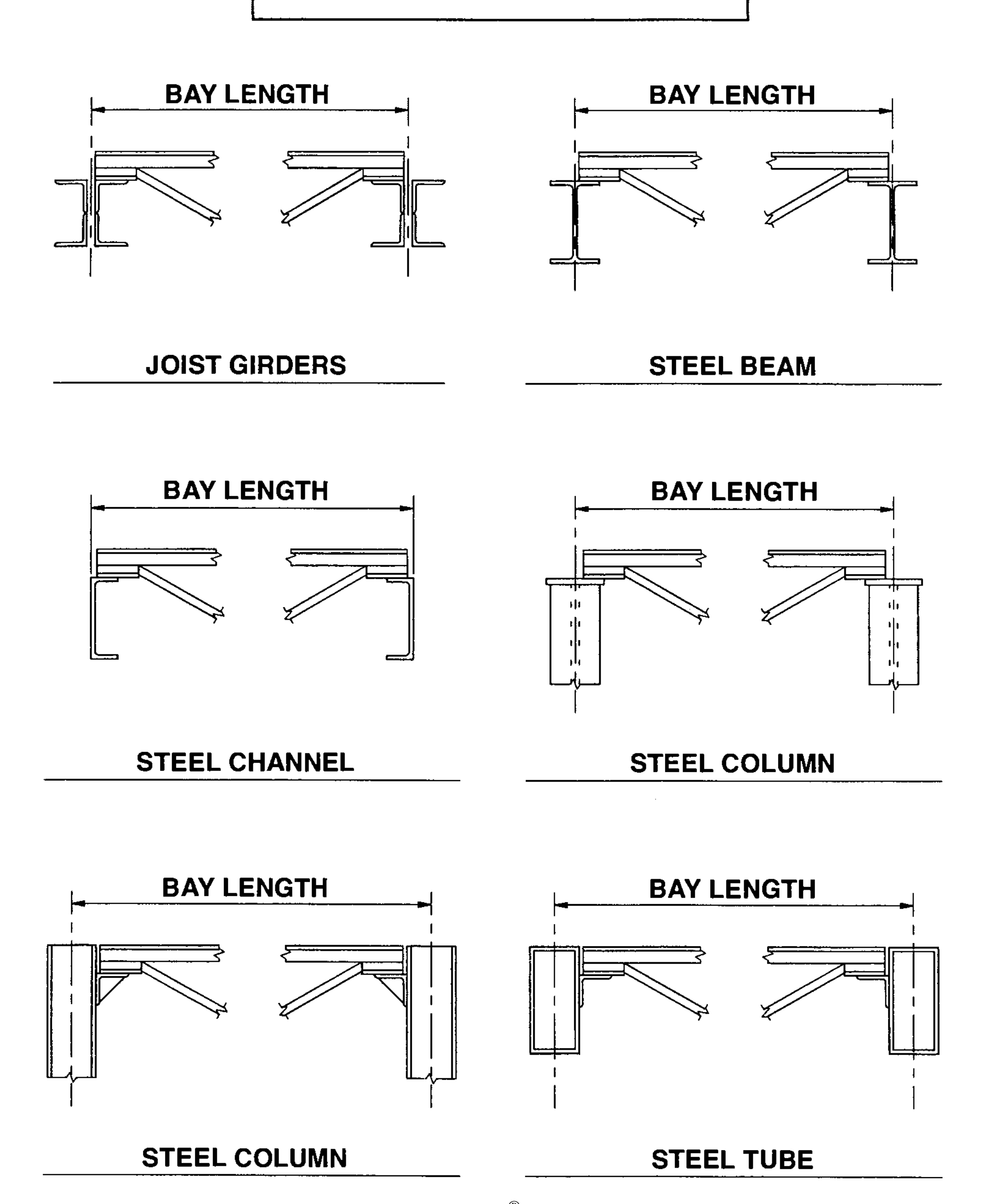
3.2.1 Definition of Span



NOTES:

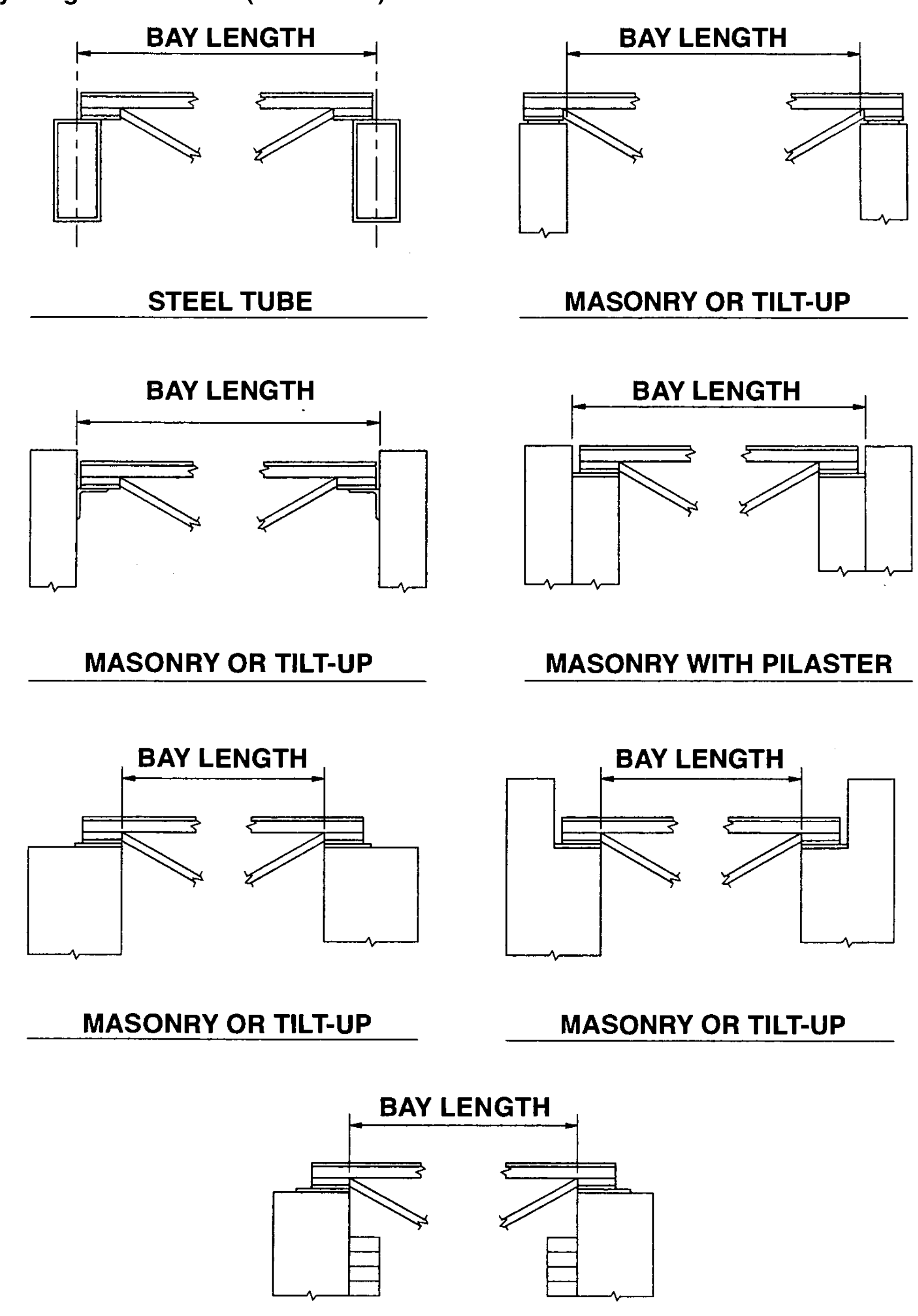
1) **DESIGN LENGTH = SPAN - 0.33 FT.**
2) **BEARING LENGTH FOR STEEL SUPPORTS SHALL NOT BE LESS THAN 2 1/2 INCHES; FOR MASONRY AND CONCRETE NOT LESS THAN 4 INCHES.**
3) **PARALLEL CHORD JOISTS INSTALLED TO A SLOPE GREATER THAN 1/2 INCH PER FOOT SHALL USE SPAN DEFINED BY THE LENGTH ALONG THE SLOPE.**

3.2.2 Bay Length Definitions



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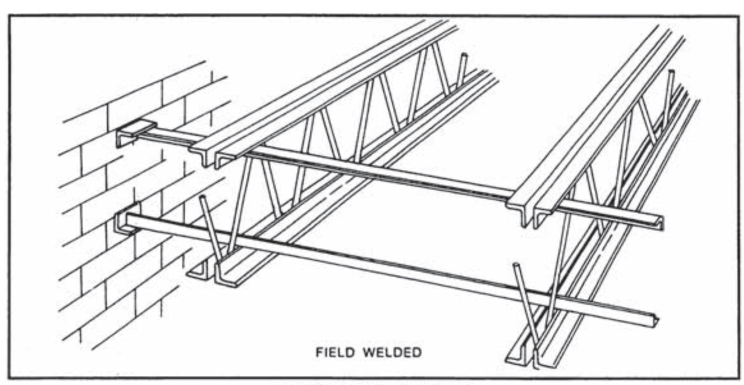
3.2.2 Bay Length Definitions (Continued)



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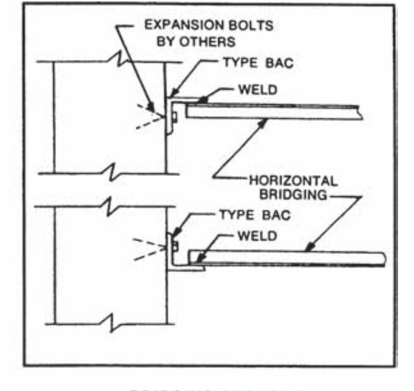
3.2.3 K Series Joists—Bridging Details

K SERIES OPEN WEB STEEL JOISTS

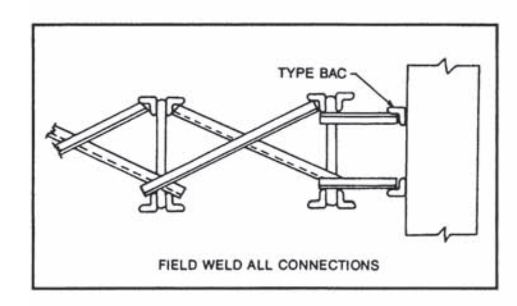


HORIZONTAL BRIDGING
SEE SJI SPECIFICATION 5.5 AND 6.

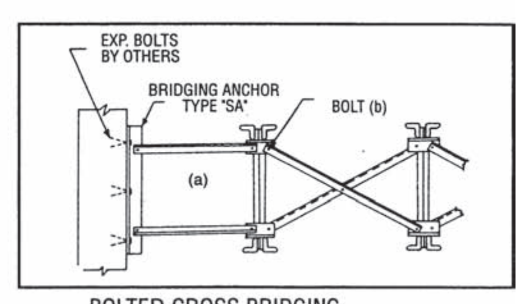
NOTE: DO NOT WELD BRIDGING TO JOIST WEB MEMBERS.
DO NOT HANG ANY MECHANICAL, ELECTRICAL, ETC. FROM BRIDGING.



BRIDGING ANCHORS
SEE SJI SPECIFICATION 5.5 AND 6.



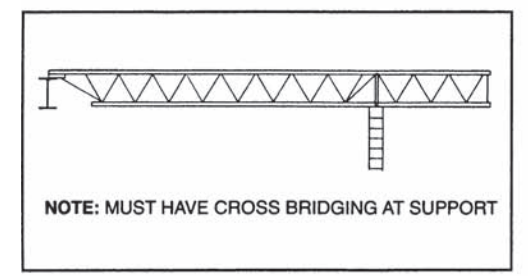
WELDED CROSS BRIDGING
SEE SJI SPECIFICATION 5.5 AND 6.
HORIZONTAL BRIDGING SHALL BE USED IN SPACE ADJACENT TO THE WALL TO ALLOW FOR PROPER DEFLECTION OF THE JOIST NEAREST THE WALL.



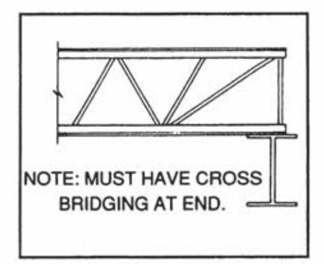
BOLTED CROSS BRIDGING
SEE SJI SPECIFICATION 5.5 AND 6.

(a) Horizontal Bridging units shall be used in the space adjacent to the wall to allow for proper deflection of the joist nearest the wall.

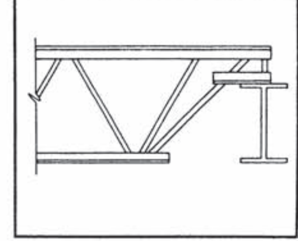
(b) For required bolt size refer to bridging table on page 136.
NOTE: Clip configuration may vary from that shown.



FULL DEPTH CANTILEVER END
SEE SJI SPECIFICATION 5.4 (d) AND 5.5 FOR BRIDGING REQUIREMENTS.



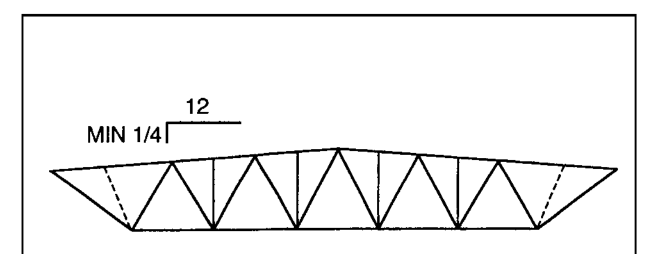
SQUARE END
SEE SJI SPECIFICATION 5.4 (d) AND 5.5 FOR BRIDGING REQUIREMENTS.



DEEP BEARINGS
CONFIGURATION MAY VARY

3.2.4 Long-Span SLH Series Joists

ACCESSORIES AND DETAILS
SLH SERIES LONGSPAN STEEL JOISTS.

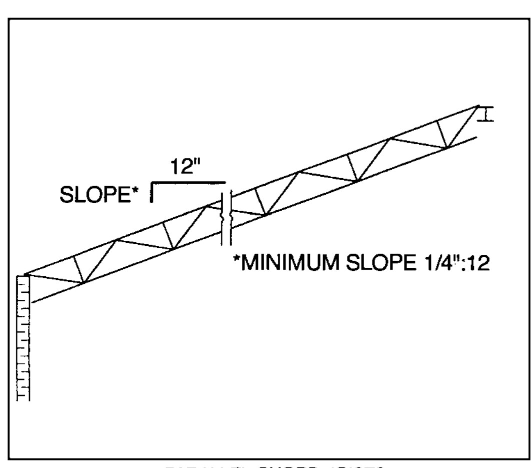


THE RECOMMENDED CONFIGURATION FOR SLH-SERIES JOISTS IS A DOUBLE PITCHED TOP CHORD WITH A MINIMUM PITCH OF 1/4 INCH PER FOOT. THE DEPTH OF THE JOIST SHALL BE THAT AT THE RIDGE OF THE JOIST. FOR OTHER CONFIGURATIONS CONTACT VULCRAFT. WEB LAYOUT MAY VARY FROM THAT SHOWN.

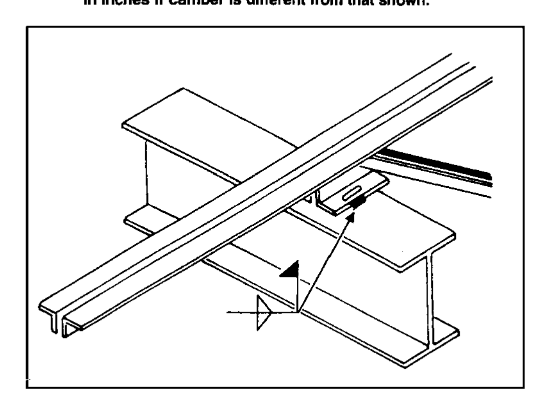
SLH-SERIES CAMBER*		
TOP CHORD LENGTH	DOUBLE PITCH JOISTS**	PARALLEL CHORD JOISTS
111'-0"	3 1/4"	5 1/4"
120'-0"	3 1/2"	6"
130'-0"	3 7/8"	7"
140'-0"	4 1/8"	8"
150'-0"	4 3/8"	8 3/4"
160'-0"	4 3/4"	9 1/2"
180'-0"	5 1/4"	10 1/2"
200'-0"	5 7/8"	11 3/4"
220'-0"	6 1/2"	13"
240'-0"	7"	14"
**JOISTS WITH TOP CHORD PITCH OF 1/4" PER FOOT OR GREATER.		

*For walls or other structural members near SLH-Series Joists provisions need to be made to match top chord elevation.

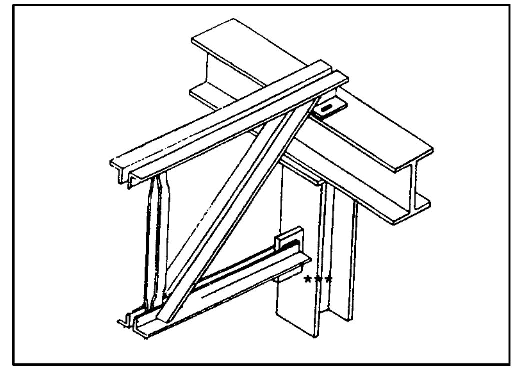
Specifying professional must provide camber requirements in inches if camber is different from that shown.



PARALLEL CHORD JOISTS
SEE SPECIFICATION 203.4 (c)



TOP CHORD EXTENSION (a)
SEE TABLE 204.8.1



BOTTOM CHORD STRUT
(SEE SPECFICATION 204.1)

*** If bottom chord is to be bolted or welded the specifying professional must provide axial loads on structural drawings.

(a) Extend top chords require the special attention of the specifying engineer.

The magnitude and location of the design loads to be supported, the deflection requirements, and the proper bracing shall be clearly indicated on the structural drawings.

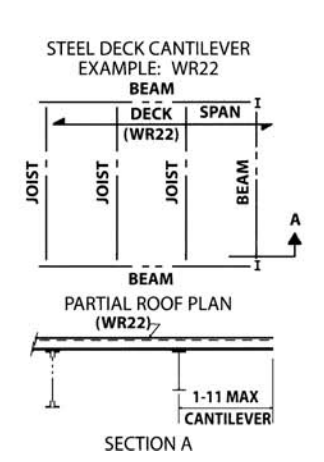
NOTE:
FOR ANY CONCENTRATED LOADS SUCH AS BASKETBALL GOALS, CURTAINS, SCORE BOARDS, HVAC UNITS, ETC. IT IS ESSENTIAL THAT THE SPECIFYING ENGINEER PROVIDE THE MAGNITUDE AND LOCATION OF ALL LOADS ON THE STRUCTURAL DRAWINGS.

3.3.0 Recommended Spans for 1½ - and 3-in. Roof Deck

RECOMMENDED MAXIMUM SPANS FOR CONSTRUCTION AND MAINTENANCE LOADS STANDARD FOR 1½ INCH AND 3 INCH ROOF DECK

	TYPE	SPAN CONDITION	SPAN		MAX. RECOMMENDED SPANS ROOF DECK CANTILEVER	
			FT.-IN.	METERS	FT.-IN.	METERS
NARROW RIB DECK	NR22	1	3′-10″	1.15 m	1′-0″	.30 m
	NR22	2 or more	4′-9″	1.45 m		
	NR20	1	4′-10″	1.45 m	1′-2″	.35 m
	NR20	2 or more	5′-11″	1.80 m		
	NR18	1	5′-11″	1.80 m	1′-7″	.45 m
	NR18	2 or more	6′-11″	2.10 m		
INTERMEDIATE RIB DECK	IR22	1	4′-6″	1.35 m	1′-2″	.35 m
	IR22	2 or more	5′-6″	1.65 m		
	IR20	1	5′-3″	1.60 m	1′-5″	.40 m
	IR20	2 or more	6′-3″	1.90 m		
WIDE RIB DECK	WR22	1	5′-6″	1.65 m	1′-11″	.55 m
	WR22	2 or more	6′-6″	1.75 m		
	WR20	1	6′-3″	1.90 m	2′-4″	.70 m
	WR20	2 or more	7′-5″	2.25 m		
	WR18	1	7′-6″	2.30 m	2′-10″	.85 m
	WR18	2 or more	8′-10″	2.70 m		
DEEP RIB DECK	3DR22	1	11′-0″	3.35 m	3′-5″	1.05 m
	3DR22	2 or more	13′-0″	3.95 m		
	3DR20	1	12′-6″	3.80 m	3′-11″	1.20 m
	3DR20	2 or more	14′-8″	4.45 m		
	3DR18	1	15′-0″	4.55 m	4′-9″	1.45 m
	3DR18	2 or more	17′-8″	5.40 m		

CANTILEVER DESIGN



Notes:

1. Adjacent span: Limited to those spans determined in Section 2.4 of Roof Deck Standards. In those instances where the adjacent span is less than 3 times the cantilever span, the individual manufacturer should be consulted for the appropriate cantilever span.
2. Sidelaps must be attached at end of cantilever and at a maximum of 12 inches (300 mm) on center from end.
3. No permanent suspended loads are to be supported by the steel deck.
4. The deck must be completely attached to the supports and at the sidelaps before any load is applied to the cantilever.
5. Service loads may be more severe than indicated in section 2.4.A.7.

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3.3.1 Steel Deck Institute (SDI) Pour Stop Selection Table

ANSI/SDI-C-1.0 ATTACHMENT C2
SDI Pour Stop Selection Table

SLAB DEPTH (INCHES)	OVERHANG (INCHES)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
	POUR STOP TYPES												
4.00	20	20	20	20	18	18	16	14	12	12	12	10	10
4.25	20	20	20	18	18	16	16	14	12	12	12	10	10
4.50	20	20	20	18	18	16	16	14	12	12	12	10	10
4.75	20	20	18	18	16	16	14	14	12	12	10	10	10
5.00	20	20	18	18	16	16	14	14	12	12	10	10	
5.25	20	18	18	16	16	14	14	12	12	12	10	10	
5.50	20	18	18	16	16	14	14	12	12	12	10	10	
5.75	20	18	16	16	14	14	12	12	12	12	10	10	
6.00	18	18	16	16	14	14	12	12	12	10	10	10	
6.25	18	18	16	14	14	12	12	12	12	10	10		
6.50	18	16	16	14	14	12	12	12	12	10	10		
6.75	18	16	14	14	14	12	12	12	10	10	10		
7.00	18	16	14	14	12	12	12	12	10	10	10		
7.25	16	16	14	14	12	12	12	10	10	10			
7.50	16	14	14	12	12	12	12	10	10	10			
7.75	16	14	14	12	12	12	10	10	10	10			
8.00	14	14	12	12	12	12	10	10	10				
8.25	14	14	12	12	12	10	10	10	10				
8.50	14	12	12	12	12	10	10	10					
8.75	14	12	12	12	12	10	10	10					
9.00	14	12	12	12	10	10	10						
9.25	12	12	12	12	10	10	10						
9.50	12	12	12	10	10	10							
9.75	12	12	12	10	10	10							
10.00	12	12	10	10	10	10							
10.25	12	12	10	10	10								
10.50	12	12	10	10	10								
10.75	12	10	10	10									
11.00	12	10	10	10									
11.25	12	10	10										
11.50	10	10	10										
11.75	10	10											
12.00	10	10											

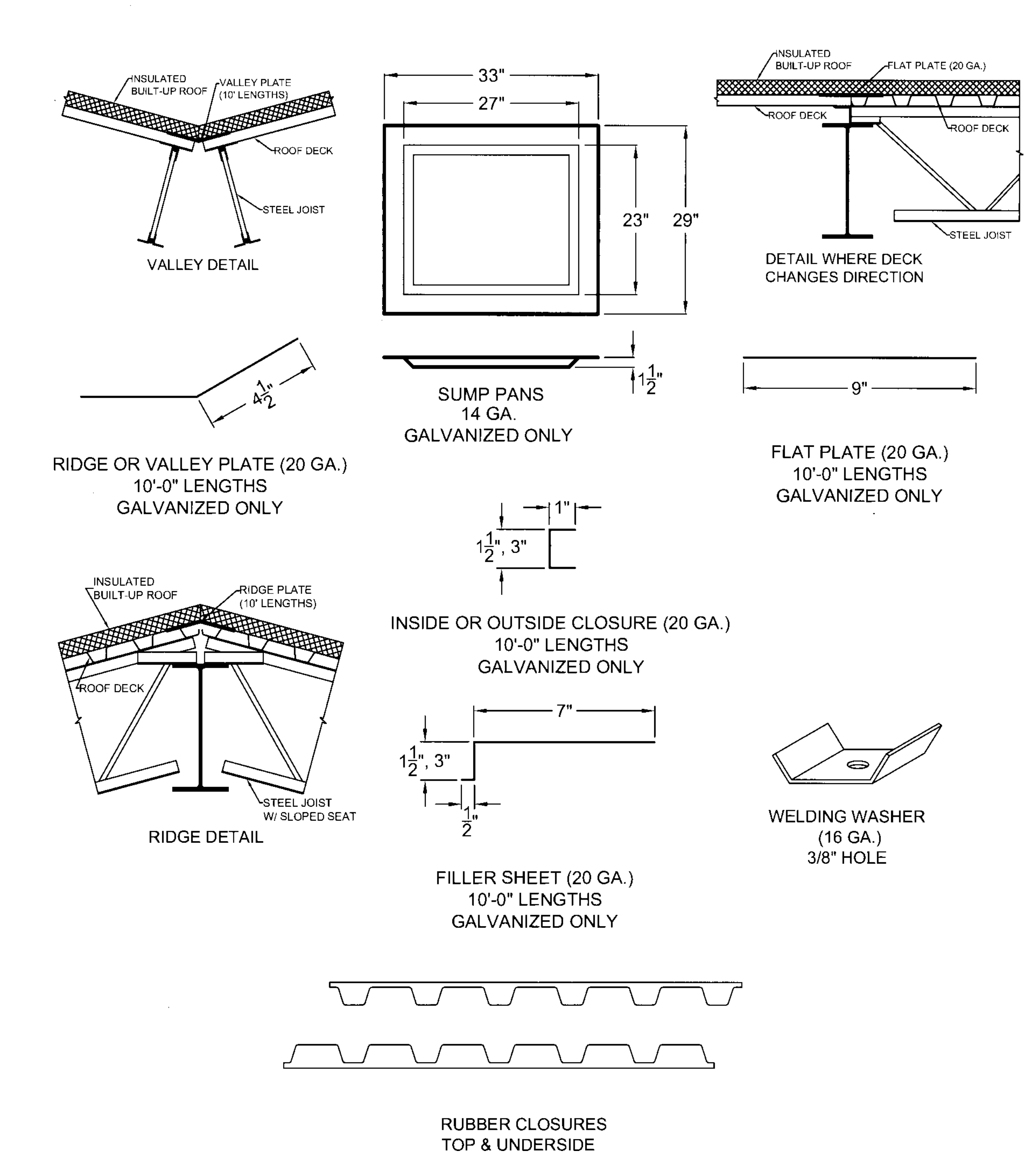
TYPES	DESIGN THICKNESS
20	0.0358
18	0.0474
16	0.0598
14	0.0747
12	0.1046
10	0.1345

1" (25 mm) fillet welds @ 12" o.c.
pour stop
slab depth
overhang
2" (50 mm) min.
see note 5
½" min.

NOTES: This Selection Chart is based on following criteria:

1. Normal weight concrete (150 PCF).
2. Horizontal and vertical deflection is limited to ¼" maximum for concrete dead load.
3. Design stress is limited to 20 KSI for concrete dead load temporarily increased by one-third for the construction live load of 20 PSF.
4. Pour Stop Selection Chart does not consider the effect of the performance, deflection, or rotation of the pour stop support which may include both the supporting composite deck and/or the frame.
5. Vertical leg return lip is recommended for all types (gages).

3.3.2 Steel Deck Accessories



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3.3.3 SDI Pour Unit Conversion Tables

ANSI/SDI-C-1.0 ATTACHMENT C3
SI Pour Units Conversion Tables

	TO CHANGE	MULTIPLY BY
LENGTH	in to mm ft to mm ft to m	25.4 (exact) 304.8 (exact) 0.3048 (exact)
AREA	in^2 to mm^2 ft^2 to m^2	645.16 (exact) 0.092903
MASS	lb to kg 2000 lb to 1000 kg lb/ft to kg/m lb/ft^3 to kg/m^3 lb/yd^3 to kg/m^3	0.453592 0.907185 1.48816 16.0185 0.593276
FORCE	lb to N kip to kN lb/in to N/m lb/ft to N/m kip/ft to kN/m psf to kN/m^2	4.44822 4.44822 175.127 14.5939 14.5939 47.880
PRESSURE	lb/in^2 to kPa lb/ft^2 to kPa kip/in^2 to MPa	6.89476 0.04788 6.89476
SECTION MODULUS	in^3 to mm^3 in^3/ft to mm^3/m	16387.1 53763.5
MOMENT OF INERTIA	in^4 to mm^4 in^4/ft to mm^4/m	416231 1365587

3.3.4 Standard Terms in Steel Design

STANDARD DEFINITIONS FOR USE IN THE DESIGN OF STEEL STRUCTURES

ASD (Allowable Strength Design). Method of proportioning structural components such that the *allowable strength* equals or exceeds the *required strength* of the component under the action of the *ASD load combinations*.

ASD Load Combination. *Load* combination in the *applicable building code* intended for *allowable strength design* (allowable stress design).

*Allowable Strength**. *Nominal strength* divided by the *safety factor*, R_n/Ω.

Applicable Building Code. Building code under which the structure is designed.

*Available Strength**. *Design strength* or *allowable strength* as appropriate.

Braced Frame. An essentially vertical truss system that provides resistance to lateral loads and provides stability for the structural system.

Cold-Formed Steel Structural Member. Shape manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature, that is, without manifest addition of heat such as would be required for hot forming.

Connection. Combination of structural elements and *joints* used to transmit forces between two or more members.

Design Load. Applied *load* determined in accordance with either *LRFD load combinations* or *ASD load combinations*, whichever is applicable.

*Design Strength**. *Resistance factor* multiplied by the *nominal strength*, ϕR_n.

Diaphragm. Roof, floor or other membrane or bracing system that transfers in-plane forces to the lateral force resisting system.

Factored Load. Product of a *load factor* and the *nominal load*.

Flexural-Torsional Buckling. Buckling mode in which a compression member bends and twists simultaneously without change in cross-sectional shape.

Girt. Horizontal structural member that supports wall panels and is primarily subjected to bending under horizontal loads, such as wind load.

Joint. Area where two or more ends, surfaces, or edges are attached. Categorized by type of fastener or weld used and the method of force transfer.

Load. Force or other action that results from the weight of building materials, occupants and their possessions, environmental effects, differential movement, or restrained dimensional changes.

Load Effect. Forces, stresses, and deformations produced in a *structural component* by the applied *loads*.

Source: American Institute of Steel Construction (AISC).

3.3.4 Standard Terms in Steel Design (Continued)

Load Factor. Factor that accounts for deviations of the *nominal load* from the actual *load,* for uncertainties in the analysis that transforms the load into a *load effect,* and for the probability that more than one extreme load will occur simultaneously.

LRFD (Load and Resistance Factor Design). Method of proportioning *structural components* such that the *design strength* equals or exceeds the *required strength* of the *component* under the action of the *LRFD load combinations.*

LRFD Load Combination. Load combination in the *applicable building code* intended for strength design (*Load and Resistance Factor Design*).

Moment Frame. Framing system that provides resistance to lateral loads and provides stability to the structural system primarily by shear and flexure of the framing members and their connections.

Nominal load. Magnitude of the *load* specified by the *applicable building code.*

Nominal Strength.* Strength of a structure or component (without the *resistance factor* or *safety factor* applied) to resist the *load effects,* as determined in accordance with this *Specification or Standard.*

Permanent Load. Load in which variations over time are rare or of small magnitude. All other *loads* are *variable loads.*

Purlin. Horizontal structural member that supports roof deck and is primarily subjected to bending under vertical loads such as snow, wind or dead loads.

Rational Engineering Analysis. Analysis based on theory that is appropriate for the situation, relevant test data if available, and sound engineering judgment.

*Required Strength.** Forces, stresses, and deformations produced in a *structural component,* determined by either *structural analysis,* for the *LRFD* or *ASD load combinations,* as appropriate, or as specified by this *Specification or Standard.*

Resistance Factor, ϕ. Factor that accounts for unavoidable deviations of the *nominal strength* from the actual strength and for the manner and consequences of failure.

Safety Factor, Ω. Factor that accounts for deviations of the actual strength from the *nominal strength,* deviations of the actual *load* from the *nominal load,* uncertainties in the analysis that transforms the *load* into a *load effect,* and for the manner and consequences of failure.

Service Load. Load under which serviceability limit states are evaluated.

Shear Wall. Wall that provides resistance to lateral loads in the plane of the wall and provides stability for the structural system.

Specification or Standard. [Editorial note: This will have to be defined for each specification or standard with language in the scope such as, The "*Specification* (or *Standard*) for the design of XXXXX" hereinafter referred to as this *Specification* (or *Standard*) shall apply........]

Specified Minimum Yield Stress. Lower limit of *yield stress* specified for a material as defined by ASTM.

Source: American Institute of Steel Construction (AISC).

3.4.0 Concrete Structures

The most common types of concrete building construction are cast-in-place, precast, tilt-up and concrete masonry units (CMUs). Slightly more than 50 percent of all low-rise buildings in the United States are built of concrete, according to the Portland Cement Association.

3.4.1 Prestressed Concrete

Concrete in which internal stresses (forces) are induced by means of prestressing steel tendons such that tensile stresses resulting from loads are counteracted to a desired degree is called prestressed concrete. There are two basic methods of prestressing concrete—pretensioning and posttensioning.

3.4.2 Pretensioned Concrete

In this process, which generally occurs in a factory environment, stressing strands are placed in tension in a concrete form prior to the placement of concrete in that form. After the concrete has cured to a specific strength, the steel stressing strands are "unloaded" so that the stresses are transferred to the concrete by the bond between the steel strands and the concrete. This process is most frequently used in the production of hollow core or solid precast plank.

3.4.3 Posttensioned Concrete

Posttensioned concrete is a field operation and, therefore, knowledgeable and experienced personnel are required in order to produce a structurally sound product in a safe environment.

Posttensioning is a method to produce structural concrete slabs, girders, and beams utilizing prestressing steel as part of a component referred to as a "tendon" which imparts prestressing forces to the concrete component. The tendons can be either encapsulated in flexible metal or plastic sheathing, or unbonded and pregreased, or mastic coated.

These tendons are individual wires as opposed to the stranded wires used in the prestressing process. Most tendons are shipped in bundles that are tied or banded and safety concerns begin even before any tendons are placed in the form. When the securing bands of the tendons are cut, the bundle becomes an uncoiled spring and care must be taken to avoid injury to those unloading the tendons prior to installation.

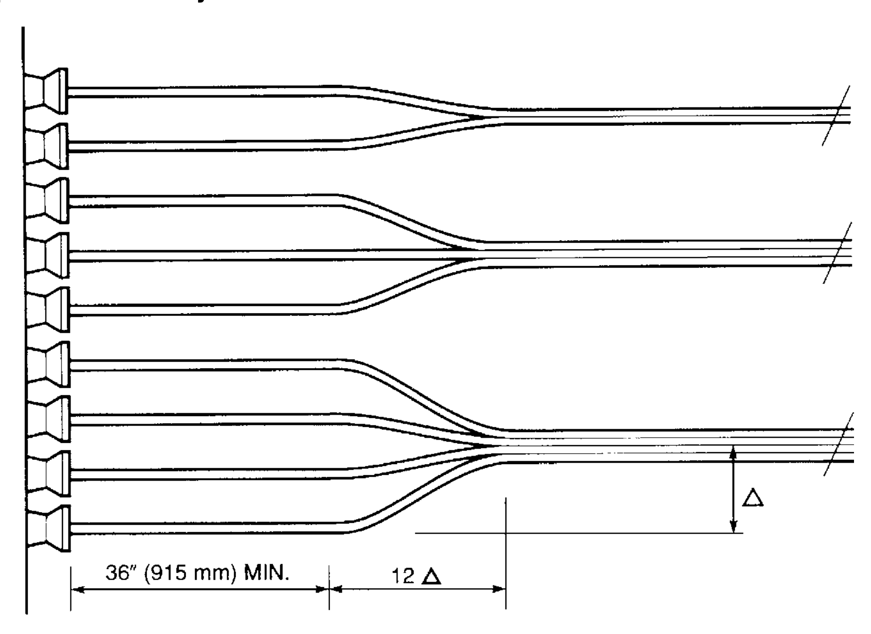
The banded tendons are usually bundled to form strand groups and not more than five ½ inch (12.7 mm) diameter tendons and not more than four 0.6 inch (15.2 mm) diameter strand tendons should be banded in one group.

When banding tendons together, care must be taken to avoid damaging the plastic sheathing.

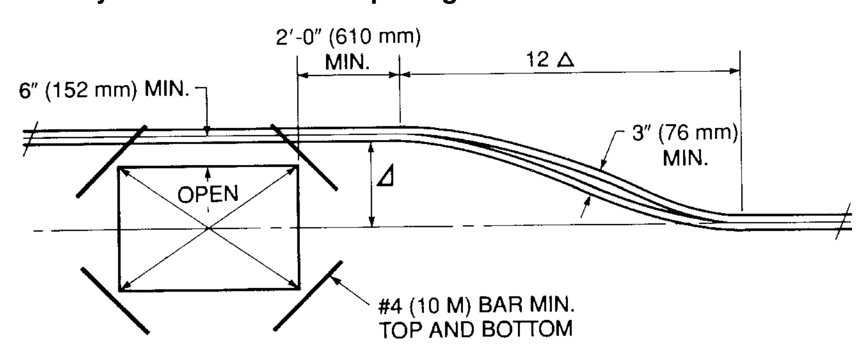
The tendons are smoothly splayed out at the anchorage as illustrated in Sec. 3.4.4. The design engineer will usually specify the procedures for installing tendons around small openings in a slab (Sec. 3.4.5). It is possible to splice tendons that may be too short by using tendon couplers (Sec. 3.4.6).

Dead end anchorages are generally attached at the posttensioning supplier's plant. A typical jacking device is shown in Sec. 3.4.7.

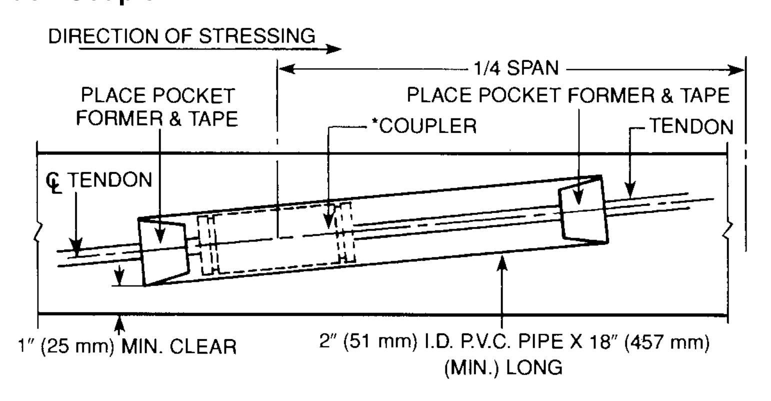
3.4.4 Typical Tendon Layout



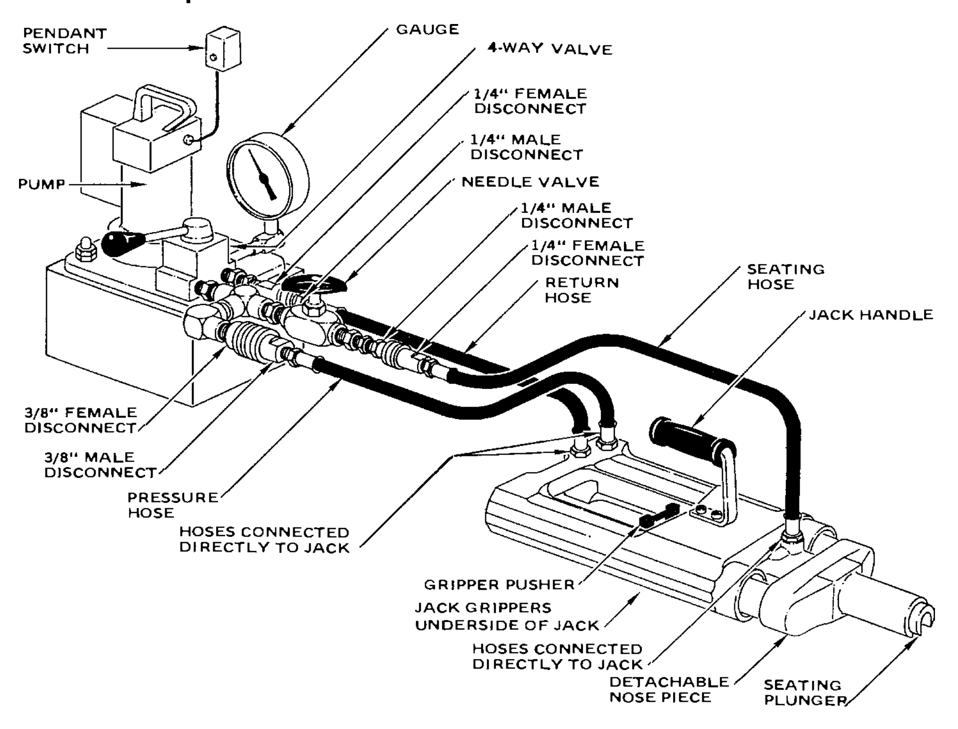
3.4.5 Tendon Layout to Avoid Small Openings



3.4.6 Tendon Coupler



3.4.7 Typical Jack Pump



3.4.8 Posttensioning Do's and Don'ts

During concrete placement:

1. Any chloride bearing chemicals in the concrete must be avoided for obvious reasons.
2. Concrete should not be placed until all tendons and reinforcing steel have been inspected and are in compliance with the design criteria and approved shop drawings.
3. During the placement of concrete, care must be taken to avoid moving the tendons out of their designated positions.
4. When truck dumping, do not place too much concrete in one location to avoid excessive spreading which may effect the placement of the tendons.
5. When pumping concrete do not rest the hose on the tendons, and move the hose nozzle in such a manner so as to avoid displacement of the tendons.
6. When placing concrete by crane and bucket, release the concrete at an elevation that avoids displacement of the tendons.
7. Do not place the vibrator on the tendons; avoid contact between the vibrator and the concrete as much as possible.

Tendon Stressing

1. Do not begin tendon stressing until break tests of concrete cylinders indicate that the concrete has attained the minimum compressive strength as specified by the design engineer.
2. Edge forms should be removed as quickly as possible to make it easier to clean out the anchor cavity while the concrete is still "green."
3. Check the integrity of the concrete, both inside the pocket and on all exposed surfaces. If there is evidence of honeycomb in the concrete, or there are voids or cracks or other signs that the concrete is substandard, DO NOT STRESS IT. One way of determining the existence of honeycombing is to tap the suspected area with a hammer. If a hollow sound is detected, notify the structural engineer for further instructions.

4. Check the tendon to ensure that it is perpendicular to the anchor and the anchor is parallel to the face of the concrete, unless design dictates otherwise.
5. Remove any excess corrosion inhibiting coatings, any dirt, sand, or concrete slurry from the tendon tails.
6. Inspect the wedges to ensure that they have been installed evenly and have been seated properly.
7. Each jack should have its own 30-amp protected circuit and all electrical circuits must be grounded.
8. Check all hose connections and make sure that a pressure gauge is installed and functioning.
9. The pump and jack should be started and checked in both extended and retracted positions. Are they any hydraulic leaks? Is the seating plunger functioning properly?

Stressing the Tendons

1. Although stressing should not commence until the proper design strength of the concrete has been achieved, it is advisable to begin stressing as soon as design strength is verified.
2. A safe, clear area must be created for the stressing crew.
3. Qualified inspection personnel must be present to measure elongations and if any variations between calculated and actual elongations consistently exceed tolerance, stressing should cease and not start up again until the cause has been determined.
4. When stressing above grade, jacks and pumps need to be secured to a fixed object to prevent equipment from being thrown off the elevated platform should a tendon fail during stressing.
5. The pump should be operated by a pendant switch, which will allow the operator to stand away from the pump should a tendon or jack gripper fail.

The Don’ts of Stressing

1. Don’t stress any tendons that contain concrete slurry inside the anchor cavity. The slurry will prevent proper seating of the wedges.
2. Don’t use the jack when it does not seat properly on the face of the anchor.
3. Don’t overstress tendons to achieve proper elongation.
4. Don’t allow obstructions in the path of the jack extension.
5. Don’t use extension cords longer than 100 feet (30 meters). All extension cords must be three wire, 12 gauge, minimum.
6. Don’t continue stressing if it appears that something is not working properly.
7. Don’t detension with loose plates, spacing shims, or piggy backing.
8. Don’t stand close to the jack or between the jack and the pump while in operation.
9. Don’t permit workers to stand in the immediate area of the jack.
10. If unsure of any operation or procedure—STOP and get professional instructions.

3.4.9 Glossary of Pretensioning and Posttensioning Terms

Anchorage A device used to anchor the tendon to the concrete member. In pretensioning, this device is used to anchor the tendon during hardening of the concrete.

Bonded tendons Tendons that are bonded to the concrete by grouting or other means and are therefore not free to move relative to the concrete.

Initial prestress The stress (force) in the tension immediately after transferring the prestressing force to the concrete. This occurs after the wedges (pieces of tapered metal with teeth that bite into the prestressing steel during transfer of the prestressing force) have been seated in the anchor.

Prestress To place a material (e.g., concrete) in a state of compression prior to the application of loads.

Prestressing steel High strength steel used in the process, most frequently made up of seven wire strands or single wires, bars, or groups of wires or bars.

Posttensioning A method of prestressing in which the tendons are tensioned after the concrete has hardened.

Sheath An enclosure in which the prestressing steel is placed to prevent bonding during concrete placement and also to protect the tendons from corrosion if the tendons are to remain unbonded.

Tendon The complete assembly that consists of the prestressing steel, sheathing, and associated anchorages.

Unbonded tendons Tendons in which the prestressing steel is permanently free to move relative to the concrete to which they are applying their prestressing forces.

The Posttensioning Institute (PCI) in Phoenix, Arizona, has developed guidelines for field personnel involved in installation, stressing, and finishing of unbonded single-strand tendons. Their guidelines represent generally accepted industry practices, but each posttensioned concrete installation may vary according to specific engineering demands.

3.4.10 Minimum Cover—Reinforcement in Prestressed Concrete

Prestressed concrete.

The following minimum concrete cover shall be provided for prestredded and nonprestressed reinforcement, ducts and end fittings, except as provided in Sections 1907.7.3.2 and 1907.7.3.3.

	MINIMUM COVER, inches (mm)
1. Concrete cast against and permanently exposed to earth	3 (76)
2. Concrete exposed to earth or weather:	
Wall panels, slabs, joists	1 (25)
Other members	$1^1/_2$ (32)
3. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists	$^3/_4$ (19)
Beams, columns:	
Primary reinforcement	$1^1/_2$ (38)
Ties, stirrups, spirals	1 (25)
Shells, folded plate members:	
No. 5 bars, W31 or D31 wire, and smaller	$^3/_8$ (9.5)
Other reinforcement	d_b but not less than $^3/_4$ (19)

3.4.11 Minimum Cover—Reinforcement in Cast-in-Place Concrete

Cast-in-place concrete (nonprestressed). The following minimum concrete cover shall be provided for reinforcement:

		MINIMUM COVER, inches (mm)
1.	Concrete cast against and permanently exposed to earth	3 (76)
2.	Concrete exposed to earth or weather:	
	No. 6 through No. 18 bar	2 (51)
	No. 5 bar, W31 or D31 wire, and smaller	$1^1/_2$ (38)
3.	Concrete not exposed to weather or in contact with ground:	
	Slabs, walls, joists:	
	No. 14 and No. 18 bar	$1^1/_2$ (38)
	No. 11 bar and smaller	$^3/_4$ (19)
	Beams, columns:	
	Primary reinforcement, ties, stirrups, spirals	$1^1/_2$ (38)
	Shells, folded plate members:	
	No. 6 bar and larger	$^3/_4$ (19)
	No. 5 bar, W31 or D31 wire, and smaller	$^1/_2$ (12.7)
4.	*Concrete tilt-up panels cast against a rigid horizontal surface, such as a concrete slab, exposed to the weather:*	
	No. 8 and smaller	*1 (25)*
	No. 9 through No. 18	*2 (51)*

3.4.12 Minimum Cover—Reinforcement in Precast Concrete

Precast concrete (Manufactured under plant control conditions). The following minimum concrete cover shall be provided for reinforcement:

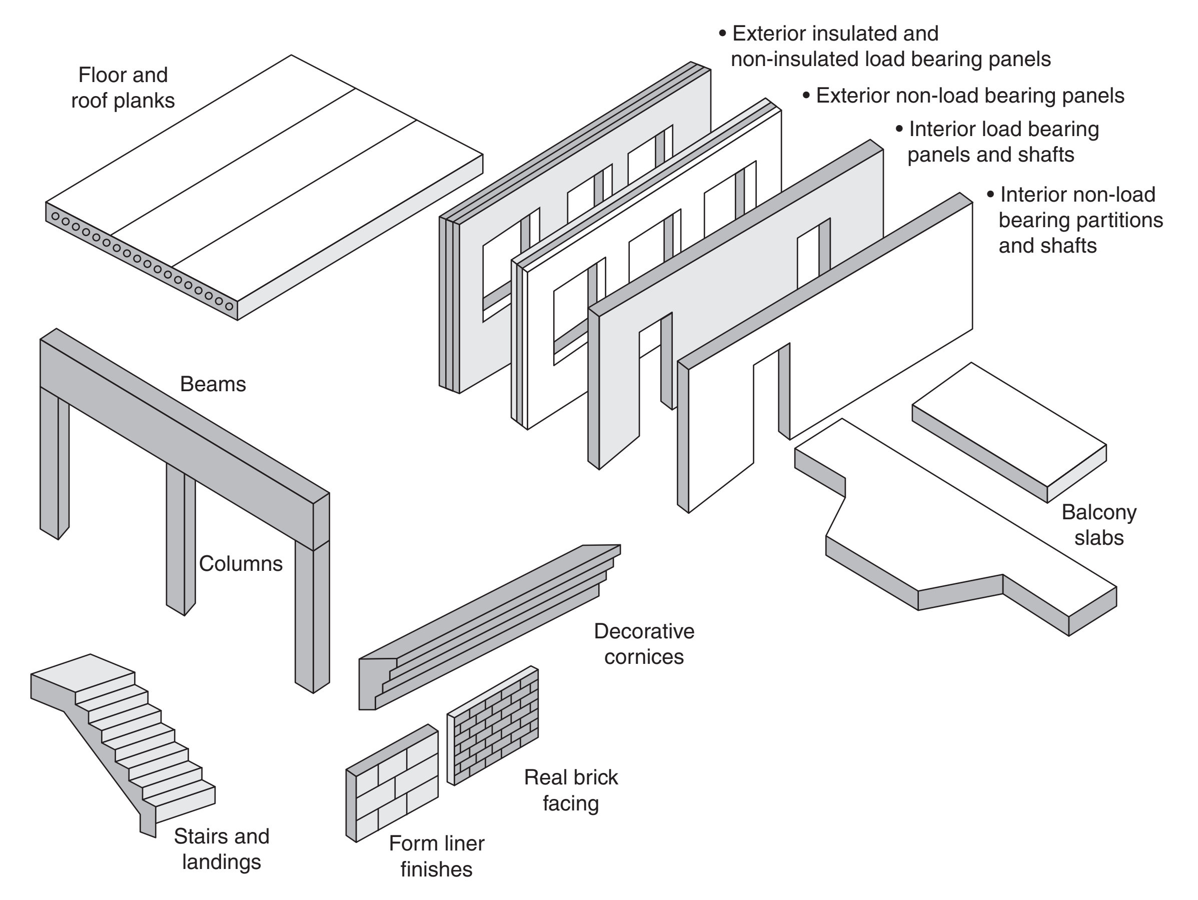
	MINIMUM COVER, inches (mm)
1. Concrete exposed to earth or weather:	
Wall panels:	
No. 14 and No. 18 bar	$1^1/_2$ (38)
No. 11 bar and smaller	$^3/_4$ (19)
Other members:	
No. 14 and No. 18 bar	2 (51)
No. 6 through No. 11 bar	$1^1/_2$ (38)
No. 5 bar W31 or D31 wire, and smaller	$1^1/_4$ (32)
2. Concrete not exposed to weather or in contact with ground:	
Slabs, walls, joists:	
No. 14 and No. 18 bar	$1^1/_4$ (32)
No. 11 bar and smaller	$^5/_8$ (16)
Beams, columns:	
Primary reinforcement	d_b but not less than $^5/_8$ (16) and need not exceed $1^1/_2$ (38)
Ties, stirrups, spirals	$^3/_8$ (9.5)
Shells, folded plate members:	
No. 6 bar and larger	$^5/_8$ (16)
No. 5 bar, W31 or D31 wire, and smaller	$^3/_8$ (9.5)

3.5.0 Precast Concrete

In the 1950s, 5000 psi (34 MPa) precast concrete was considered standard, but by the 1990s, 19,000 psi (131 MPa) precase concrete was not unusual; and by 2008, precast concrete with a strength in excess of 21,750 psi (150 MPa) was being installed in buildings. Precast concrete components offer rapid construction on the site, high quality because of the controlled environment in which the components were built, and durability.

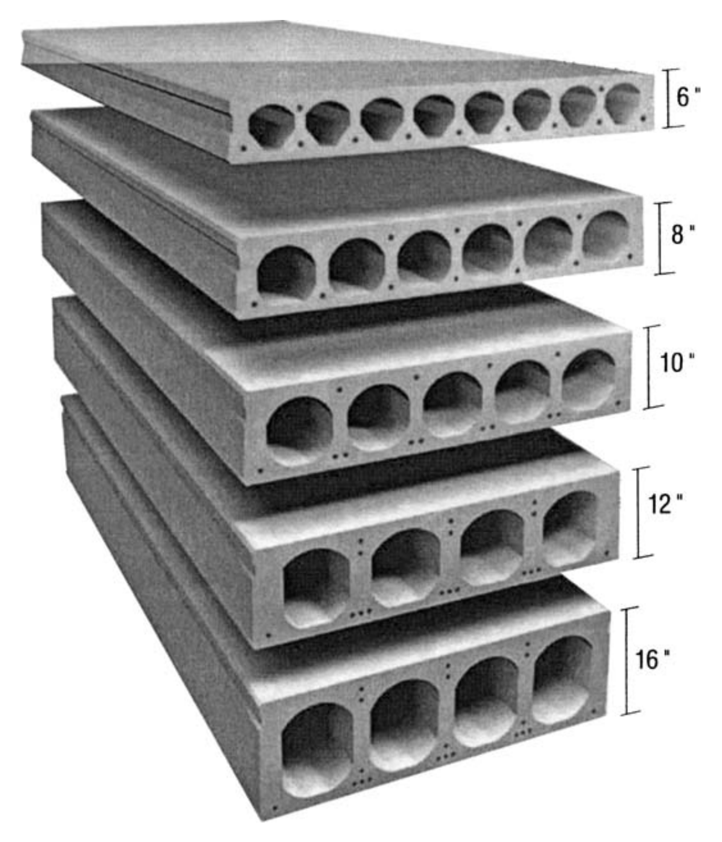
3.5.1 Precast Components

Structural elements such as beams, columns, and hollow-core floor slabs and architectural panels that form the building's skin and cast stone components comprise the panoply of precast concrete elements.



Source: Oldcastle Precast Building Systems.

3.5.2 Hollow-Core Floor Sections



Source: Oldcastle Precast Building Systems.

3.6.0 Tilt-Up Construction

Like the name implies, this type of concrete structure consists of pouring concrete wall panels in a form on grade at the jobsite and tilting (lifting) them in place.

3.6.1 Footing Preparation

Spread footings are most often used for tilt-up construction, but pier-type footings are also employed as a suitable foundation. Tilt-up walls bear on the footings, and therefore establishing the correct footing elevation is critical to ensuring that the top elevation of the tilt-up panel will be at the desired elevation. When the tilt-up panels are set on a slab-on-grade, the surface of the slab should be smooth so when it receives the panel, there will be minimal impact on the aesthetics of the wall-slab joint.

3.6.2 Wall Alignment

One way to ensure alignment of a wall panel to slab is to snap a chalk line on the slab that will correspond with the panel alignment against which the panels will be placed. Standard tilt-up panel thicknesses are 5½ in. (13.9 cm) and 7¼ in. (18.4 cm). Door and window openings are formed after the panel perimeter forms have been set in place, and these openings are braced to prevent bowing or movement as the concrete is placed around them. Standard Grade 40 or 60 rebars are used as wall reinforcement, and plastic chairs are used in lieu of steel to avoid rust bleeding through the face of the panel.

3.6.3 Embeds and Inserts

After the rebars are in place, prefabricated plates with lugs are cast into the panel to secure it to the footing and adjacent panels. Insets also provide the attachment points for the lifting hardware and braces.

3.6.4 Lifting

The erection sequence is developed prior to the lifting process, and all crew members must be made aware of all safety precautions to be strictly adhered to during the tilt-up process. Crane operation, bracing, anchorage, and cable release procedures must all be reviewed prior to any lifting operation.

3.7.0 Masonry—A Glossary of Terms

ADMIXTURES - Materials added to cement, aggregate and water such as water repellents, air-entraining or plasticizing aids, pigments, or aids to retard or speed up setting.

AGGREGATES - Inert particles such as sand, gravel, rock, which when bound together with portland cement and water, form concrete.

ANCHOR TIES - Any type of fastener used to secure masonry veneer to a support backing, such as another wall, usually for tension value.

ASTM - American Society for Testing and Materials.

AREAS -

Bedded Area - The area of the surface of a masonry unit which is in contact with mortar in the plane of the joint.

Gross Area - The total cross-sectional area of any plane encompassed by the outer periphery of any specified section.

Net Area - The gross cross-sectional area at any plane minus the area of ungrouted cores, notches, cells, unbedded areas, etc. Net area is the actual surface area of a cross-section of masonry.

BOND -

Adhesion Bond - The adhesion between masonry units and mortar or grout.

Mechanical Bond - Units laid so that they lap over each other in successive courses. Includes quarter bond, third bond and half or common bond.

Running Bond - Lapping of units in successive courses so that the vertical head joints lap. Placing vertical mortar joints centered over the unit below is called center bond, or half bond, while lapping 1/3 or 1/4 is called third or quarter bond.

Stack Bond - A bonding pattern where no unit overlaps either the one above or below, all head joints form a continuous vertical line. Also called plumb joint bond, straight stack, jack bond, jack on jack, and checker board bond.

BOND BEAM - One or more courses of masonry units poured solid and reinforced with longitudinal reinforcing bars. (See Bond Beam Block under CONCRETE MASONRY UNIT.)

CELL (Core) - The molded open space in a concrete masonry unit.

CHASE - A continuous recess built into a wall to receive pipes, ducts, etc.

CLEANOUT - An opening at the bottom of a grout space of sufficient size and spacing to allow the removal of debris.

CMACN - Concrete Masonry Association of California and Nevada.

COLLAR JOINT - The vertical longitudinal joint between wythes of masonry.

COMPOSITE MASONRY - Multiwythe masonry members acting together as a single member in resisting loads.

COMPRESSIVE STRENGTH - The maximum load required to fracture the masonry unit by applying a compressive force to the upper and lower surface of the unit. Expressed as either gross compressive strength, or net compressive strength. (See *Strengths, CMUBasics*, page CMUB-4.)

CONCRETE MASONRY UNIT - (See *Configurations, CMUBasics*, page CMUB-1.)

A-Block - A hollow unit with one end closed and the opposite end open. Term often used for fence unit as a support for 4 inch wide wall. Also called open end block.

Bond Beam Block - A hollow unit with portions of end and cross webs formed to permit a continuous channel for horizontal reinforcing steel and grout. Also called channel block.

Concrete Block - A concrete masonry unit made from portland cement and suitable aggregates with or without the inclusion of other materials.

H-Block - A hollow unit with a single cell in center of unit with both ends open. Used as a fence pilaster to support 4 inch wide wall.

Hollow Masonry Unit - A masonry unit whose net cross-sectional area in every plane parallel to the bearing surface is less than 75 percent of the gross cross-sectional area in the same plane.

Lintel Block - A hollow unit to permit the forming of a continuous channel for reinforcing steel and grout.

Open End Block - A hollow unit with one end closed and the opposite end open. A **Double Open End** unit has both ends open.

Pilaster Block- Concrete masonry units designed for use in construction of plain or reinforced concrete masonry pilasters and columns.

Sash Block - Concrete masonry unit which has an end slot for use in openings to receive metal window frames and pre- molded expansion joint material.

Scored Block - Block with grooves to provide patterns, as for example, to simulate raked joints.

Sill Block - A solid concrete masonry unit used for sills or openings.

Solid Masonry Unit - Refers to concrete masonry units in which the vertical cores are less than 25 percent of the cross-sectional area.

COURSE - A continuous horizontal layer of masonry units.

DIMENSIONS - (See *Dimensions and Sizes, CMUBasics*, page CMUB-1)

Actual Dimensions - The measured dimensions of a designated item; for example, a designated masonry unit or wall, as used in the structure. The

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3.7.0 Masonry—A Glossary of Terms (Continued)

masonry unit or wall,as used in the structure. The actual dimension shall not vary from the specified dimension by more than the amount in the appropriate material standard.

Nominal Dimensions - Generally equal to its specified dimensions plus the thickness of the joint with which the unit is to be laid.

Specified Dimension The dimensions specified for the manufacture or construction of masonry, masonry units, joints or any other component of a structure. Unless otherwise stated, all calculations shall be made using or based on specified dimensions.

EFFLORESCENCE - A whitish powder resulting from the deposition of soluble salts on the surface of masonry, concrete, or soil.

FACE SHELL - The side wall of a hollow concrete masonry unit.

FACED WALL - A wall in which the facing and backing are so bonded or otherwise tied as to act as a composite element. As opposed to VENEER.

f'_m - the specified compressive strength of masonry at the age of 28 days. (See *Strengths, CMUBasics,* Page CMUB-4.)

GROUT - A concrete mixture of sand, pea gravel (usually), water and sometimes admixture, which is poured or pumped into the vertical cells and bond beams. Grout encases the reinforcing steel and adds to the strength and fire rating of a block wall.

GROUT LIFT - The height to which grout is placed in a cell, collar joint, or wythe without intermission.

GROUT POUR - The total height of masonry wall to be poured prior to the erection of additional masonry. A pour may consist of one or more lifts.

JOINTS -

Bed Joint - The mortar joint that is horizontal at the time the masonry units are placed.

Dry Joint - A mortarless joint.

Head Joint - The mortar joint between units in the same wythe, usually vertical.

Struck Joint - Any mortar joint which has been finished with the trowel.

JOINT REINFORCEMENT - Steel wire, bar or prefabricated reinforcement which is placed in mortar bed joints.

JOINTING - The process of finishing mortar joints with a tool. Also called tooling.

LIME -

Hydrated Lime - Quicklime treated with only enough water to satisfy its chemical demand. Packaged in powdered form, does not require slaking.

MASONRY - Construction of building units bonded together with mortar, grout, or other accepted methods.

Reinforced masonry - Masonry construction in which reinforcement acts in conjunction with the masonry to resist forces.

MODULAR DIMENSION - A dimension based on a given module, usually eight (8) inches in the case of concrete block masonry.

MORTAR - A plastic mixture of cementitious materials, fine aggregate and water, with or without the inclusion of other specified materials.

PILASTER - An integral portion of the wall which projects on one or both sides and acts as a vertical beam, a column, an architectural feature, or any combination thereof.

POINTING - Filling mortar into a joint after the masonry unit is laid.

PRISM - Units mortared together, generally in stack bond, forming a wallette or assemblage to simulate "in wall construction", grouted per specification requirements. This is the standard test sample for determination of f'_m.

REBAR - Reinforcing steel bars of various sizes and shapes used to strengthen masonry.

SHELL - The outer portion of a hollow masonry unit as placed in masonry.

TEMPER - To moisten mortar and re-mix to the proper consistency for use. Also called retempering.

TOOLING - See JOINTING.

TUCK POINTING - The filling in with fresh mortar of cut-out or defective mortar joints.

VENEER - A masonry facing which is attached to the backup but not so bonded as to act with it under load. As opposed to FACED WALL.

WALLS -

Bonded Walls - A wall in which two or more of its wythes of masonry are adequately bonded together to act as a structural unit.

Hollow-Unit Masonry Wall - That type of construction made with hollow masonry units in which the units are laid and set in mortar.

WALL TIE - A mechanical fastener which connects wythes of masonry to each other or to other materials.

WEB - An interior solid portion of a hollow masonry unit as placed in masonry.

WYTHE - The portion of a wall which is one masonry unit in thickness. Also called a tier. A collar joint is not considered a wythe.

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3.7.1 History of Masonry

The first recorded brick masonry units were made by the Egyptians in 10,000 B.C. and the Romans used brick in many of their structures 2000 years ago. The Great Pyramid of Giza in Egypt is the first recorded use of mortar. Brick manufacture and use occurred in the mid-1600s and was patterned on English methods and practices. It was not until 1930, however, that cavity wall construction (as we know it today) was introduced into the United States from Europe as a means of controlling moisture. This method provides a physical separation between the inner and outer wythes to serve as a drainage cavity for water, which would be expelled through weep holes in the outer wythe.

Masonry today is primarily devoted to the construction of brick, block, structural clay products, and natural and cast stone. Walls can be basically categorized as load-bearing or non-load-bearing walls, cavity walls, veneer walls, and solid walls. No matter the type of material used or the method by which the masonry wall is constructed, two components remain crucial: mortar and wall reinforcement.

3.7.2 Mortar

Mortar is the bonding agent that holds all of the masonry units together. Bond strength is the crucial element that differs from its close relative concrete, where compressive strength is the most important physical property.

Mortar serves four functions:

1. It bonds the masonry units together and seals the space between them.
2. It allows for dimensional variations in the masonry units while still maintaining a high degree of levelness.
3. It bonds to the reinforcing steel in the wall.
4. It provides an added decorative effect to the wall in as much as various colors or tooled joints can be introduced.

3.7.2.1 Mortar Types

- *Type M* High compressive strength (2500 psi average), containing greater durability than other types. Therefore, it is generally recommended for unreinforced masonry walls below grade.
- *Type S* Reasonable high compressive strength (1800 psi average) and having great tensile bond strength. It is usually recommended for reinforced masonry walls, where maximum flexural strength is required.
- *Type N* Midrange compressive strength (750 psi average) and suitable for general above-grade masonry construction for parapets and chimneys.
- *Type O* Load compressive strength (350 psi average) and suitable for interior non-load-bearing masonry walls.
- *Type K* Very low compressive strength (75 psi average) and occasionally used for interior non-load-bearing walls, where permitted by local building codes.

Workability or plasticity of the mortar is an essential characteristic of proper mortar mixes. The mortar must have both cohesive and adhesive qualities when it makes contact with the masonry units. Hardness or high strength is not necessarily a measure of durability. Mortar that is stronger than the masonry units to which it is applied might not "give," thereby causing stress to be relieved by the masonry units. This could result in these units cracking or spalling.

3.7.2.2 Mortar Additives

Like concrete, mortar admixtures can be added for many reasons:

- *Accelerators* To speed up the setting time by 30 to 40% and increase the 24-hour strength. Some accelerators contain calcium chloride and are not acceptable to the architect/engineer.
- *Retarders* Extends the board life of the mortar by as much as 4 to 5 hours. It slows down the set time of mortar when temperatures exceed 70°F.
- *Integral water repellents* It reduces water absorption and is useful when a single wythe wall will be exposed to the elements.
- *Bond modifiers* Improves adhesion to block. It is particularly useful when glass block walls are being built.
- *Corrosion inhibitors* Used in marine environments where salt air could penetrate the mortar and begin to corrode any wall reinforcement.

3.7.2.3 Mortar Testing

Mortar testing is performed by the "prism" test method, in accordance with ASTM E 447, Method B. The compressive strength is the average strength of three prisms.

Net area compressive strength of concrete masonry units, psi (MPa)		Net area compressive strength of masonry, psi[1] (MPa)
Type M or S mortar	Type N mortar	
1250 (8.6)	1300 (9.0)	1000 (6.9)
1900 (13.1)	2150 (14.8)	1500 (10.3)
2800 (19.3)	3050 (21.0)	2000 (13.8)
3750 (25.8)	4050 (27.9)	2500 (17.2)
4800 (33.1)	5250 (36.2)	3000 (20.1)

[1]For units of less than 4 in. (102 mm) height, 85 percent of the values listed.

3.7.3 CMU Basics

Dimensions and Sizes

Three terms are used in referring to dimensions: specified, actual, and nominal.

Specified dimensions are those specified for the manufacture of masonry units or the construction of masonry. Calculations are based on specified dimension.

Actual dimensions are the measured dimensions of the unit. ASTM Standards allow the actual dimensions a permissible variation from the specified dimension. Refer to individual product sections for their respective tolerances.

Nominal dimensions are those used in stating unit size. They are equal to the specified dimensions plus the thickness of the mortar joint. The nominal dimensions compensate for a 3/8 inch joint for precision and split face, and a 1/2-inch joint for Slumpstone™.

For Example:

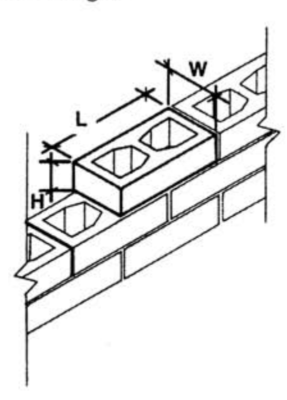
Precision

nominal dimension	8 x 4 x 16
specified dimension	7 5/8 x 3 5/8 x 15 5/8

Slumpstone™

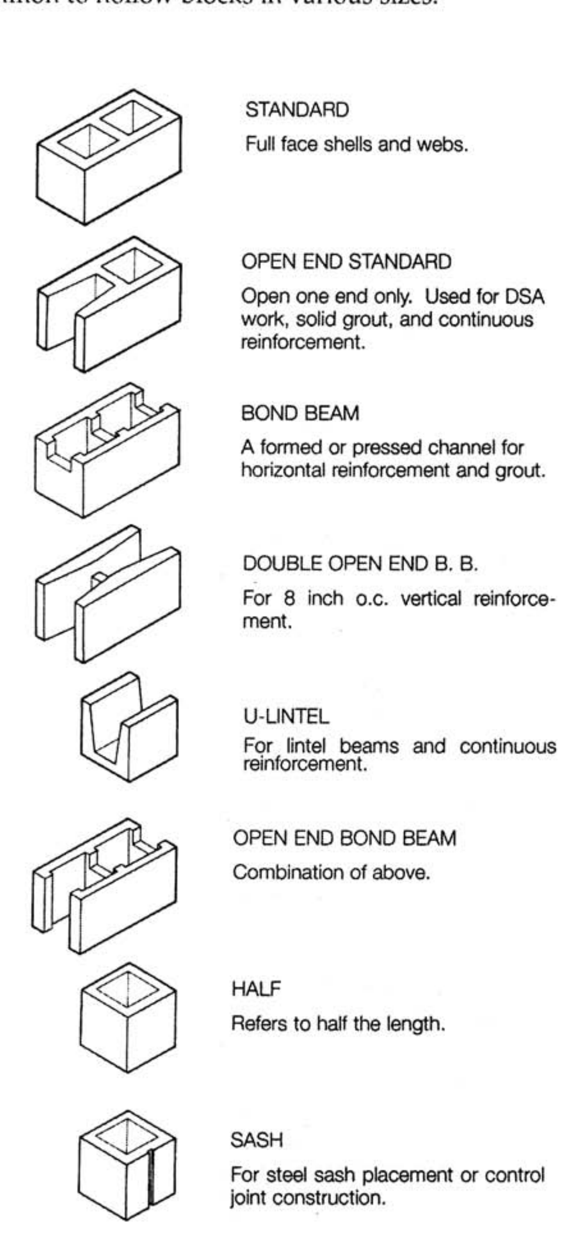
nominal dimension	8 x 4 x 16
specified dimension	7 1/2 x 3 1/2 x 15 1/2

Dimensions must be stated in proper order—width, height, and length (WHL). For example, an 8-inch wide, 16-inch long, 4-inch high unit is termed an 8x4x16. Reversing any two dimensions will describe a completely different unit. Using the same example stated as 4x8x16 would indicate a unit 4 inches wide and 8 inches high (not 8 inches wide and 4 inches high).



Configurations

CMU are either solid or hollow. By definition a solid unit is 75% or more in net area. Hollow units are most commonly used in structural applications. Solid units are used in composite masonry and for veneers. The basic configurations shown below are common to hollow blocks in various sizes.



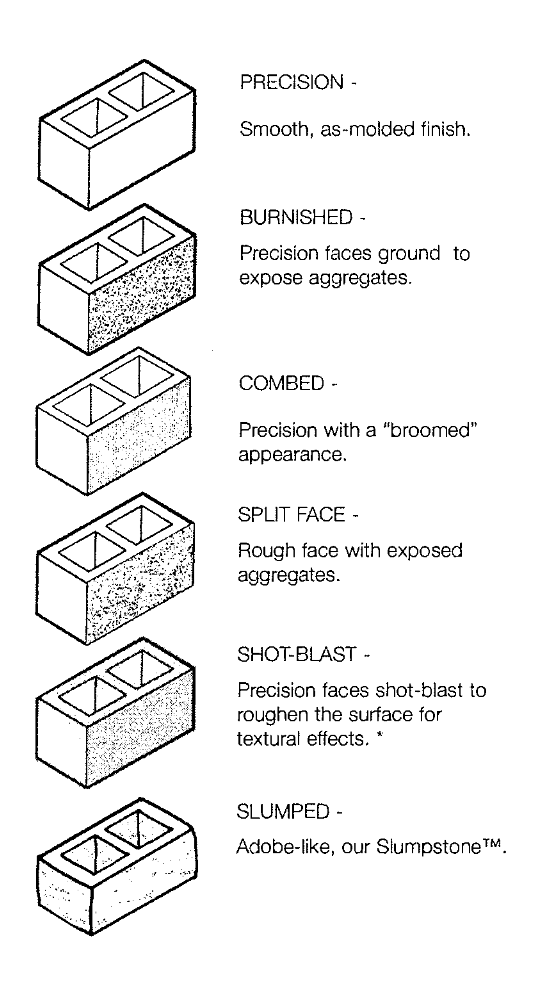
Additional elements may be added to some units for design effects, including vertical scores, deep scores, flutes, and projections.

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3.7.3 CMU Basics (Continued)

Textures

Manufactured textures include:



Variations of texture are inherent in cmu and create the warmth and character of a cmu wall. Please refer to each product section for specific information.

* Note that field sandblasting is a popular, successful method of achieving an alternative texture. After the walls are built, and other trades that may work around the walls are finished, a clean-up sandblast is often done as the most effective method to remove the staining and soiling that normally occurs during construction. By applying a heavier blast that gets in to the aggregates, you can create an attractive texture at the same time the walls are cleaned.

Sandblasting the completed wall allows maximum control over uniformity of texture as the entire field can be seen, giving the contractor opportunity to adjust as needed. Shot-blasting is essentially an automated process that cannot adjust for variability in the hardness of individual units, therefore the degree of texturing will vary from unit to unit.

Colors

Angelus Block offers an extensive selection of standard and special order integral colors. (See the Colors & Textures Chart.) Your representative can offer samples and specific information to assist in color specifications.

Cmu manufactured by Angelus Block are of the highest quality and uniformity available. However, variations may occur in color and shade, in natural gray or integral color, as a result of color ranges in raw materials over which we have no control. A statement of color, then, refers to a range of color. Further, exact color duplication from run to run cannot be guaranteed.

Color will be affected by differences in weight (density) or strength. A weight classification will require a specific aggregate mix, which will create its own natural gray and have an effect on any added coloring agent. For example, a color in mediumweight will differ somewhat from the same color in lightweight. Similarly, High-Stress units have a different mix design; as a result, their color will not be exactly the same as non-High-Stress units. Contact your representative should the weight or strength to be specified differ from that indicated on a given sample.

Occasionally, new construction may be required to match an existing wall or structure, dictating the color of new cmu match the color of existing cmu. This circumstance raises a host of considerations such as the age and extent of weathering of the "old" cmu, possible differences in aggregate from the time of its manufacture to the present, and the fact that a good match now may not last as the "new" cmu weathers.

We strongly suggest that specifications for such a project avoid the simplicity of the "match existing" statement. Instead, we recommend consulting your Angelus Block representative to determine the availability and/or feasibility of current materials to reasonably match the existing wall and whether the best solution would be integral color or staining natural gray to best match existing cmu. It is advantageous for everyone involved if this is specified in advance of the masonry bid, much before the start of the

3.7.3 CMU Basics (Continued)

masonry work, thereby avoiding last minute scrambling for suitable materials.

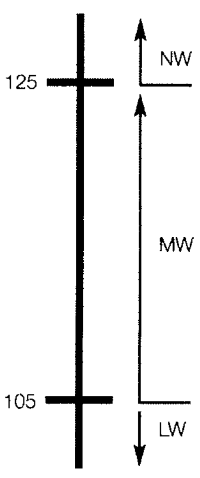
Sources of raw materials may differ from plant to plant. So, too, will color differ from plant to plant. One location's gray or color will not match another location's gray or color. Even if they bear an identical color name, product from one plant should not be mixed with another's if *it is intended they match.* Consult your representative for color compatibility from plant to plant.

Note: As extensive as our color palette is, you can extend it further by combining two or more colors in the same wall. This gives you more control over final effect, and results in rich, intense colors. Blending colors in a single cmu batch tends to muddy them and mute their clarity.

Weights

Standards applicable to cmu contain three classifications of weight, expressed in pounds per cubic foot: normalweight, mediumweight, and lightweight.

Normalweight is 125 lbs./cu. ft. and over. Units stocked in normalweight include Slumpstone™ units and fence units (stucco block, Catalina, Balboa, etc.). Certain colors are stocked only in normalweight - all Slumpstone™ colors, and precision colors such as Colorcrete (pink), Fawn, Mission Tan, and #500 (yellow).



Mediumweight is less than 125 to 105 lbs./cu.ft. "Structural" types and sizes are stocked most extensively in mediumweight. In addition to precision and split face gray, a scored split and standard color are normally available.

Lightweight is less than 105 lbs./cu. ft. Normally stocked in selected sizes in gray.

Note: both mediumweight and lightweight units are made with "lightweight" aggregates. To specify a cmu solely on the statement that it be made with lightweight aggregates does not provide adequate definition.

Of the three weights, normalweight is the least expensive and lightweight is the most expensive. Mediumweight is most popular (and therefore has greatest availability) for structural applications as its moderate weight and cost generally offer the best labor production to material cost ratio.

For average weights per units and wall area, please see charts in the General Information section, page General - 1.

3.7.3 CMU Basics (Continued)

Strengths

Strength is expressed in two distinct ways:

Cmu compressive strength is the psi calculated from the net area of the individual unit. The minimum average net compressive strength per ASTM C 90 is 1900 net psi.

f′m specified compressive strength of masonry is the value used in design of the masonry wall. This is the strength specification that really matters, as it is the stength upon which the engineer's design is based. When the design utilizes prescribed minimum strengths of cmu and grout per their respective standards, the given *f′m* is 1500 psi based on net area.

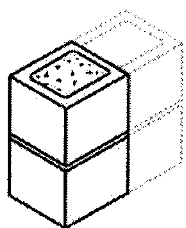
Notice it is the strength of *masonry*, not units. It is the compressive strength of the assemblage of masonry units, mortar, and grout.

IBC Section 2105.2 has two provisions for complying with the specified *f′m* value: 1) by unit strength method, and, 2) by prism test method.

Unit strength method. IBC allows an "assumed" value of *f′m* to be selected based upon specifying the net compressive strength of the masonry *unit.* (Table 2105.2.2.1.2) For example, specifying a High-Stress unit at 3750 net psi, an *f′m* of 2500 net psi would be allowed without substantiation by prism test.

Note: The California Building Code does not allow the unit strength method for design strengths over 1500 net psi. Prism testing must be used.

Prism testing. Although prism tests require more coordination in project management, compression testing of prisms does offer the most accurate determination of *f′m*. A prism is a sample assemblage of masonry units, mortar joints, and grout similar to the one shown. For concrete masonry, such testing has suggested "a rule of thumb" relationship between prism compressive strength and the individual strengths of cmu and grout from which it is constructed. where the *f′m* is approximately 80% of the cmu and grout strengths.



For example, a High-Stress unit of 3750 net psi should facilitate an *f′m* of 3000 net psi. (The IBC requires the compressive strength of grout must be equal to or greater than the *f′m*. However, the "80%" rule was based on UBC's requirement of grout strength equal to or greater than the cmu compressive strength.)

When the f′m value exceeds 1500 net psi, we recommend specifying the f′m as required by design and verifying compliance by means of prism testing. In this way, testing more reliably portrays actual construction, and full values are realized in design and materials.

Prism testing also allows the contractor to submit and supply a combination of cmu and grout most advantageous for the project schedule. The conservatively high cmu values utilized by the unit strength method may force materials to be made on special order with significant lead times. Many times, however, the *f′m* can be satisfied by available materials coupled with an appropriate grout strength.

	CMU	*f′m*	
Unit Type	Net Area	80% of cmu and grout[1]	IBC[2]
Std. cmu per ASTM C90	1,900	1,520	1,500
High Stress	3,750	3,000[3]	2,500

1. Grout compressive strength equal to or greater than cmu compressive strength.
2. IBC Table 2105.2.2.1.2.
3. Verified by prism test.

3.7.4 Standard Weights of CMUs

Normal weight CMU weighs 125 lbs/cubic foot and higher
Medium weight CMU weighs between 105 lbs/cubic foot and 125 lbs/cubic foot
Lightweight CMU weighs less than 105 lbs/cubic foot

3.8.0 Modular Brick Size—Nominal with ½-in. Joint

Modular: 4" × 2-2/3" × 8"
Engineer modular: 4" × 3½" × 8"
Closure modular: 4" × 4" × 8"
Roman: 4" × 2" × 12"
Norman: 4" × 2-2/3" × 12"
Engineer Norman: 4" × 3½" × 12"
Utility: 4" × 4" × 12"

3.8.1 Nominal Height of Brick and Block Walls

COURSES	REGULAR 4 2¼" bricks + 4 equal joints =					MODULAR 3 bricks + 3 joints =	CONCRETE BLOCKS	
	10" ¼" joints	10½" ⅜" joints	11" ½" joints	11½" ⅝" joints	12" ¾" joints	8"	3⅝" blocks ⅜" joints	7⅝" blocks ⅜" joints
1	2½"	2⅝"	2¾"	2⅞"	3"	2 11/16"	4"	8"
2	5"	5¼"	5½"	5¾"	6"	5 5/16"	8"	1'4"
3	7½"	7⅞"	8¼"	8⅝"	9"	8"	1'0"	2'0"
4	10"	10½"	11"	11½"	1'0"	10 11/16"	1'4"	2'8"
5	1'0½"	1'1⅛"	1'1¾"	1'2⅜"	1'3"	1'1 5/16"	1'8"	3'4"
6	1'3"	1'3¾"	1'4½"	1'5¼"	1'6"	1'4"	2'0"	4'0"
7	1'5½"	1'6⅜"	1'7¼"	1'8⅛"	1'9"	1'6 11/16"	2'4"	4'8"
8	1'8"	1'9"	1'10"	1'11"	2'0"	1'9 5/16"	2'8"	5'4"
9	1'10½"	1'11⅝"	2'0¾"	2'1⅞"	2'3"	2'0"	3'0"	6'0"
10	2'1"	2'2¼"	2'3½"	2'4¾"	2'6"	2'2 11/16"	3'4"	6'8"
11	2'3½"	2'4⅞"	2'6¼"	2'7⅝"	2'9"	2'5 5/16"	3'8"	7'4"
12	2'6"	2'7½"	2'9"	2'10½"	3'0"	2'8"	4'0"	8'0"
13	2'8½"	2'10⅛"	2'11¾"	3'1⅜"	3'3"	2'10 11/16"	4'4"	8'8"
14	2'11"	3'0¾"	3'2½"	3'4¼"	3'6"	3'1 5/16"	4'8"	9'4"
15	3'1½"	3'3⅜"	3'5¼"	3'7⅛"	3'9"	3'4"	5'0"	10'0"
16	3'4"	3'6"	3'8"	3'10"	4'0"	3'6 11/16"	5'4"	10'8"
17	3'6½"	3'8⅝"	3'10¾"	4'0⅞"	4'3"	3'9 5/16"	5'8"	11'4"
18	3'9"	3'11¼"	4'1½"	4'3¾"	4'6"	4'0"	6'0"	12'0"
19	3'11½"	4'1⅞"	4'4¼"	4'6⅝"	4'9"	4'2 11/16"	6'4"	12'8"
20	4'2"	4'4½"	4'7"	4'9½"	5'0"	4'5 5/16"	6'8"	13'4"
21	4'4½"	4'7⅛"	4'9¾"	5'0⅜"	5'3"	4'8"	7'0"	14'0"
22	4'7"	4'9¾"	5'0½"	5'3¼"	5'6"	4'10 11/16"	7'4"	14'8"
23	4'9½"	5'0⅜"	5'3¼"	5'6⅛"	5'9"	5'1 5/16"	7'8"	15'4"
24	5'0"	5'3"	5'6"	5'9"	6'0"	5'4"	8'0"	16'0"
25	5'2½"	5'5⅝"	5'8¾"	5'11⅞"	6'3"	5'6 11/16"	8'4"	16'8"
26	5'5"	5'8¼"	5'11½"	6'2¾"	6'6"	5'9 5/16"	8'8"	17'4"
27	5'7½"	5'10⅞"	6'2¼"	6'5⅝"	6'9"	6'0"	9'0"	18'0"
28	5'10"	6'1½"	6'5"	6'8½"	7'0"	6'2 11/16"	9'4"	18'8"
29	6'0½"	6'4⅛"	6'7¾"	6'11⅜"	7'3"	6'5 5/16"	9'8"	19'4"
30	6'3"	6'6¾"	6'10½"	7'2¼"	7'6"	6'8"	10'0"	20'0"
31	6'5½"	6'9⅜"	7'1¼"	7'5⅛"	7'9"	6'10 11/16"	10'4"	20'8"
32	6'8"	7'0"	7'4"	7'8"	8'0"	7'1 5/16"	10'8"	21'4"
33	6'10½"	7'2⅝"	7'6¾"	7'10⅞"	8'3"	7'4"	11'0"	22'0"
34	7'1"	7'5¼"	7'9½"	8'1¾"	8'6"	7'6 11/16"	11'4"	22'8"
35	7'3½"	7'7⅞"	8'0¼"	8'4⅝"	8'9"	7'9 5/16"	11'8"	23'4"
36	7'6"	7'10½"	8'3"	8'7½"	9'0"	8'0"	12'0"	24'0"
37	7'8½"	8'1⅛"	8'5¾"	8'10⅜"	9'3"	8'2 11/16"	12'4"	24'8"
38	7'11"	8'3¾"	8'8½"	9'1¼"	9'6"	8'5 5/16"	12'8"	25'4"
39	8'1½"	8'6⅜"	8'11¼"	9'4⅛"	9'9"	8'8"	13'0"	26'0"
40	8'4"	8'9"	9'2"	9'7"	10'0"	8'10 11/16"	13'4"	26'8"
41	8'6½"	8'11⅝"	9'4¾"	9'9⅞"	10'3"	9'1 5/16"	13'8"	27'4"
42	8'9"	9'2¼"	9'7½"	10'0¾"	10'6"	9'4"	14'0"	28'0"
43	8'11½"	9'4⅞"	9'10¼"	10'3⅝"	10'9"	9'6 11/18"	14'4"	28'8"
44	9'2"	9'7½"	10'1"	10'6½"	11'0"	9'9 5/16"	14'8"	29'4"
45	9'4½"	9'10⅛"	10'3¾"	10'9⅜"	11'3"	10'0"	15'0"	30'0"
46	9'7"	10'0¾"	10'6½"	11'0¼"	11'6"	10'2 11/16"	15'4"	30'8"
47	9'9½"	10'3⅜"	10'9¼"	11'3⅛"	11'9"	10'5 5/16"	15'8"	31'4"
48	10'0"	10'6"	11'0"	11'6"	12'0"	10'8"	16'0"	32'0"
49	10'2½"	10'8⅝"	11'2¾"	11'8⅞"	12'3"	10'10 11/16"	16'4"	32'8"
50	10'5"	10'11¼"	11'5½"	11'11¾"	12'6"	11'1 5/16"	16'8"	33'4"

3.8.2 Estimating Concrete Masonry

NOMINAL LENGTH OF CONCRETE MASONRY WALLS BY STRETCHERS

(Based on units 15⅝" long and half units 7⅝" long with ⅜" thick head joints)

LENGTH OF WALL	NO. OF UNITS	LENGTH OF WALL	NO. OF UNITS	LENGTH OF WALL	NO. OF UNITS	LENGTH OF WALL	NO. OF UNITS	LENGTH OF WALL	NO. OF UNITS	LENGTH OF WALL	NO. OF UNITS
0′-8″	½	20′-8″	15½	40′-8″	30½	60′-8″	45½	80′-8″	60½	100′-8″	75½
1′-4″	1	21′-4″	16	41′-4″	31	61′-4″	46	81′-4″	61	101′-4″	76
2′-0″	1½	22′-0″	16½	42′-0″	31½	62′-0″	46½	82′-0″	61½	102′-0″	76½
2′-8″	2	22′-8″	17	42′-8″	32	62′-8″	47	82′-8″	62	102′-8″	77
3′-4″	2½	23′-4″	17½	43′-4″	32½	63′-4″	47½	83′-4″	62½	103′-4″	77½
4′-0″	3	24′-0″	18	44′-0″	33	64′-0″	48	84′-0″	63	104′-0″	78
4′-8″	3½	24′-8″	18½	44′-8″	33½	64′-8″	48½	84′-8″	63½	104′-8″	78½
5′-4″	4	25′-4″	19	45′-4″	34	65′-4″	49	85′-4″	64	105′-4″	79
6′-0″	4½	26′-0″	19½	46′-0″	34½	66′-0″	49½	86′-0″	64½	106′-0″	79½
6′-8″	5	26′-8″	20	46′-8″	35	66′-8″	50	86′-8″	65	106′-8″	80
7′-4″	5½	27′-4″	20½	47′-4″	35½	67′-4″	50½	87′-4″	65½	107′-4″	80½
8′-0″	6	28′-0″	21	48′-0″	36	68′-0″	51	88′-0″	66	108′-0″	81
8′-8″	6½	28′-8″	21½	48′-8″	36½	68′-8″	51½	88′-8″	66½	108′-8″	81½
9′-4″	7	29′-4″	22	49′-4″	37	69′-4″	52	89′-4″	67	109′-4″	82
10′-0″	7½	30′-0″	22½	50′-0″	37½	70′-0″	52½	90′-0″	67½	110′-0″	82½
10′-8″	8	30′-8″	23	50′-8″	38	70′-8″	53	90′-8″	68	110′-8″	83
11′-4″	8½	31′-4″	23½	51′-4″	38½	71′-4″	53½	91′-4″	68½	111′-4″	83½
12′-0″	9	32′-0″	24	52′-0″	39	72′-0″	54	92′-0″	69	112′-0″	84
12′-8″	9½	32′-8″	24½	52′-8″	39½	72′-8″	54½	92′-8″	69½	112′-8″	84½
13′-4″	10	33′-4″	25	53′-4″	40	73′-4″	55	93′-4″	70	113′-4″	85
14′-0″	10½	34′-0″	25½	54′-0″	40½	74′-0″	55½	94′-0″	70½	114′-0″	85½
14′-8″	11	34′-8″	26	54′-8″	41	74′-8″	56	94′-8″	71	114′-8″	86
15′-4″	11½	35′-4″	26½	55′-4″	41½	75′-4″	56½	95′-4″	71½	115′-4″	86½
16′-0″	12	36′-0″	27	56′-0″	42	76′-0″	57	96′-0″	72	116′-0″	87
16′-8″	12½	36′-8″	27½	56′-8″	42½	76′-8″	57½	96′-8″	72½	116′-8″	87½
17′-4″	13	37′-4″	28	57′-4″	43	77′-4″	58	97′-4″	73	117′-4″	88
18′-0″	13½	38′-0″	28½	58′-0″	43½	78′-0″	58½	98′-0″	73½	118′-0″	88½
18′-8″	14	38′-8″	29	58′-8″	44	78′-8″	59	98′-8″	74	118′-8″	89
19′-4″	14½	39′-4″	29½	59′-4″	44½	79′-4″	59½	99′-4″	74½	119′-4″	89½
20′-0″	15	40′-0″	30	60′-0″	45	80′-0″	60	100′-0″	75	120′-0″	90

NOMINAL HEIGHT OF CONCRETE MASONRY WALLS BY COURSES

(Based on units 7⅝" high ⅜" thick mortar joints)

HEIGHT OF WALL	NO. OF UNITS	HEIGHT OF WALL	NO. OF UNITS	HEIGHT OF WALL	NO. OF UNITS	HEIGHT OF WALL	NO. OF UNITS
0′-8″	1	8′-8″	13	16′-8″	25	24′-8″	37
1′-4″	2	9′-4″	14	17′-4″	26	25′-4″	38
2′-0″	3	10′-0″	15	18′-0″	27	26′-0″	39
2′-8″	4	10′-8″	16	18′-8″	28	26′-8″	40
3′-4″	5	11′-4″	17	19′-4″	29	27′-4″	41
4′-0″	6	12′-0″	18	20′-0″	30	28′-0″	42
4′-8″	7	12′-8″	19	20′-8″	31	28′-8″	43
5′-4″	8	13′-4″	20	21′-4″	32	29′-4″	44
6′-0″	9	14′-0″	21	22′-0″	33	30′-0″	45
6′-8″	10	14′-8″	22	22′-8″	34	30′-8″	46
7′-4″	11	15′-4″	23	23′-4″	35	31′-4″	47
8′-0″	12	16′-0″	24	24′-0″	36	30′-0″	48

HOW TO USE THESE TABLES

The tables on this page are an aid to estimating and designing with standard concrete masonry units. The following are examples of how they can be used to advantage.

Example:

Estimate the number of units required for a wall 76′ long and 12′ high.

From table: 76′ = 57 units
12′ = 18 courses

57 × 18 = 1026 = No. masonry units required

Example:

Estimate the number of units required for a foundation 24′ × 30′ = 11 courses high.

2 (24 + 30) = 108′ = distance for a foundation

From table: 108′ = 81 units

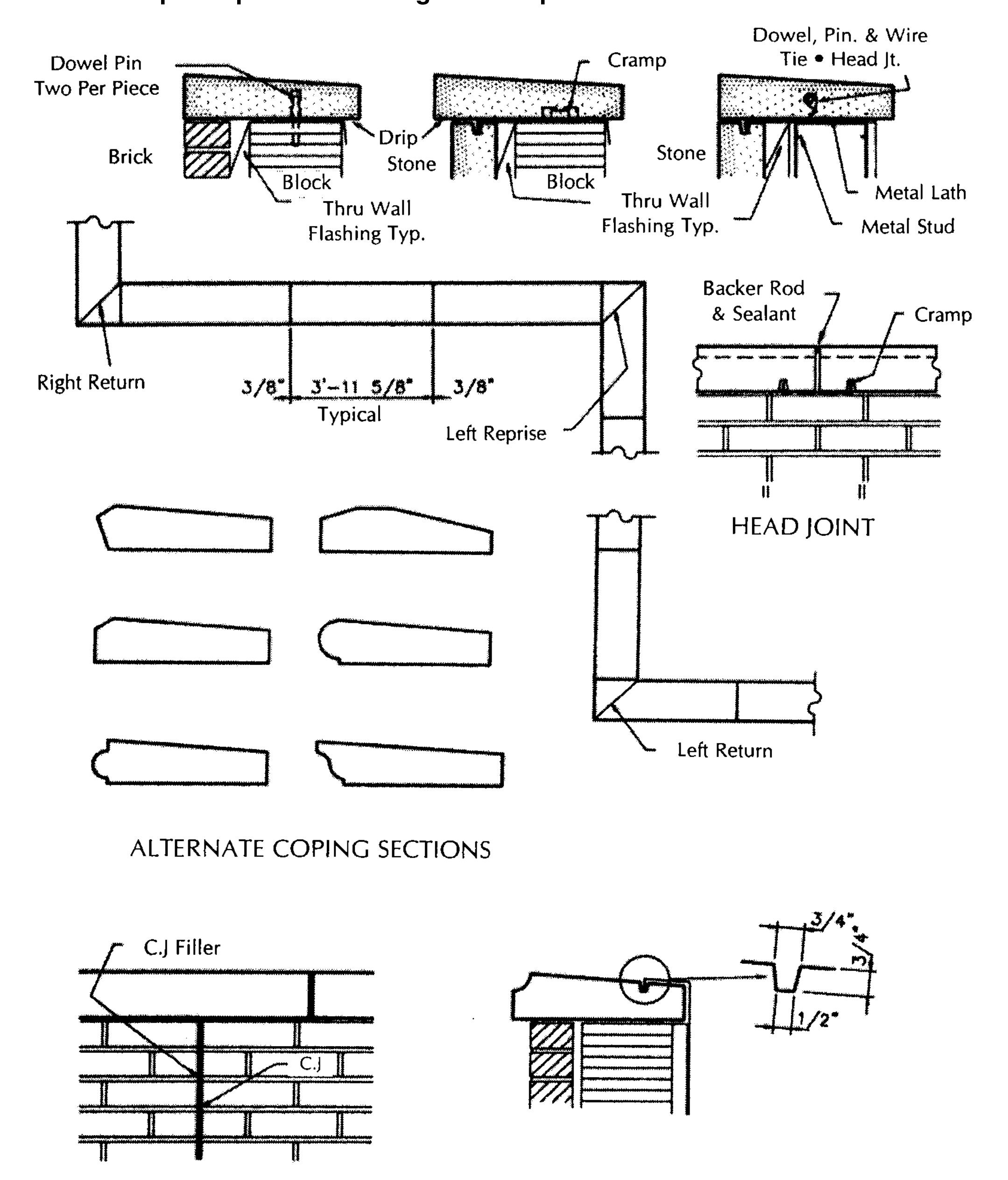
81 × 11 = 891 = No. masonry units required.

This table can also be useful in the layout of a building on a modular basis to eliminate cutting of units. Example: If design calls for a wall 41′ long it can be found from the table that making wall 41′-4″, will eliminate cutting units and consequent waste. Example: If the distance between two openings has been tentatively established at 2′-9″, consulting the table will show that 2′-8″ dimension would eliminate cutting of units.

3.9.0 Cast Stone

Cast stone is an architectural concrete building product that combines the strength of reinforced concrete with the appearance of natural stone. Cast stone products consist of Portland cement; fine and coarse aggregates, usually granite, quartz, limestone, natural or manufactured sands, and high-performance chemical additives.

3.9.1 Cast Stone Parapet Caps with Flashing and Weep Holes



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3.9.2 Decorative Column Details

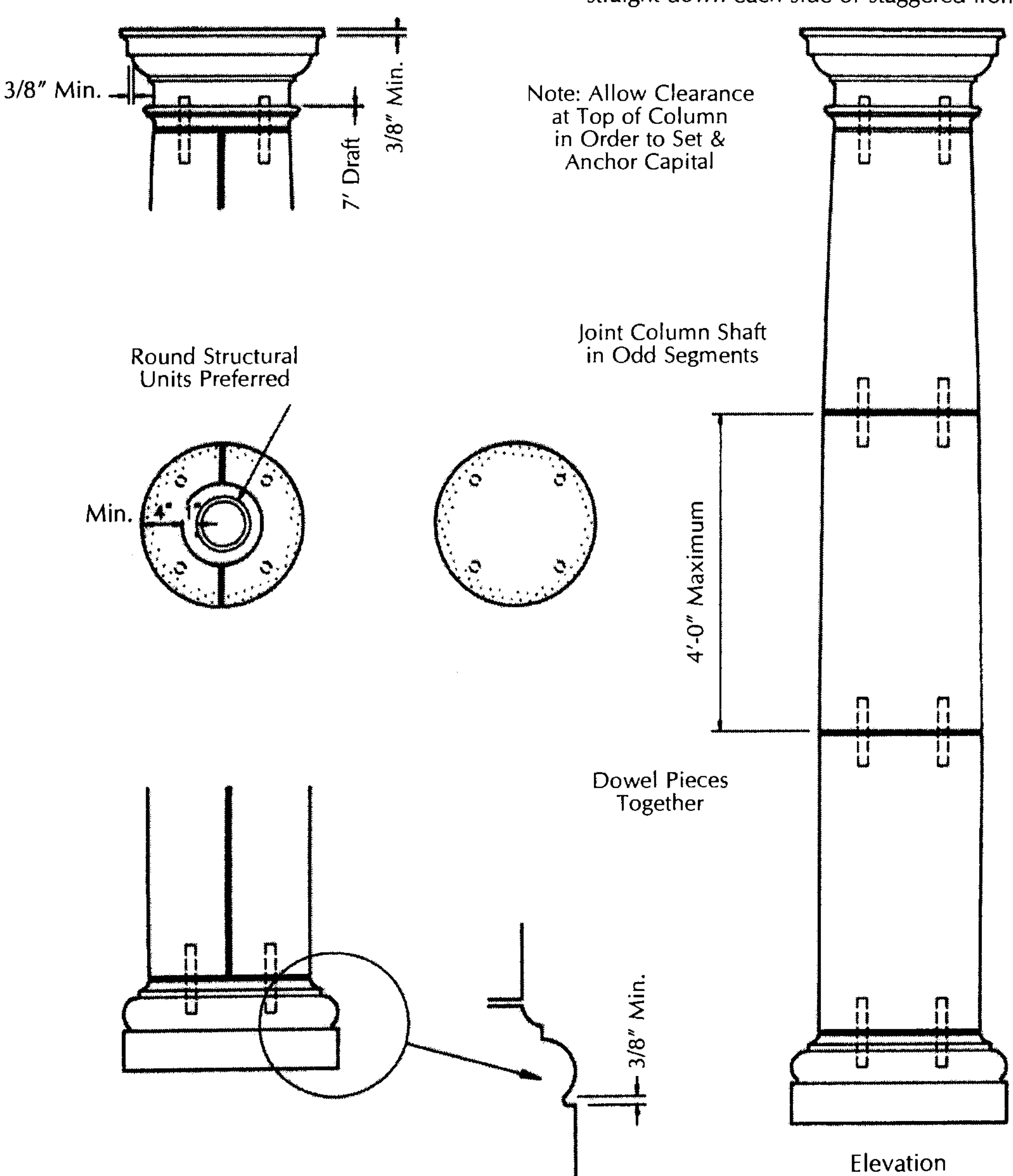
MISC. COLUMN DETAILS - PLATE #27

Allowance for draft and feather edges in the production mould represent careful considerations which are made by the manufacturer. In most instances these accommodations have no effect on the design but deliver a major effect on the quality of the casting. Your Cast Stone Institute producer member pays a great deal of attention to these details.

Columns are usually manufactured solid. Often, U-shaped column covers are attached to structural steel. This removes the stone columns from the critical construction schedule path and prevents the columns from damage during construction.

Anchorage of columns and column covers is accomplished with dowel pins connecting units together, combining with standard anchors as shown on page 74 for tying back to the structure.

Vertical jointing of column covers can be made straight down each side or staggered from side to side.



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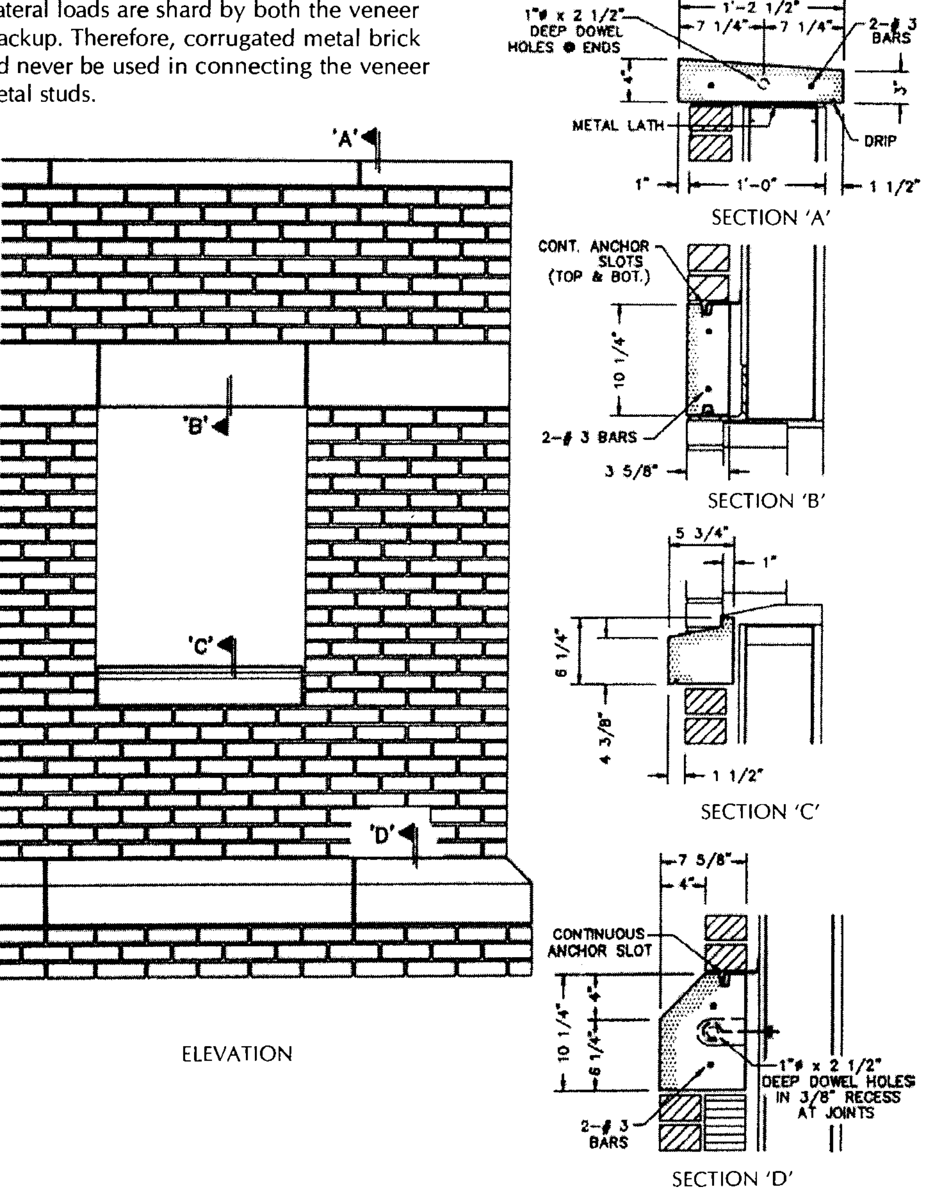
3.9.3 Water Table, Sill, Header, and Copings

Details of anchoring with metal stud wall systems can usually be derived from the conventional methods after special attention is given to the structural considerations of this type of wall system.

Anchors tie the veneer to the backup; they must be stiff enough to resist tension and compression, but flexible enough to not resist shear. This flexibility permits in-plane differential movements between the backup and the veneer which are essential to the wall system. Lateral loads are shard by both the veneer and the backup. Therefore, corrugated metal brick ties should never be used in connecting the veneer wall to metal studs.

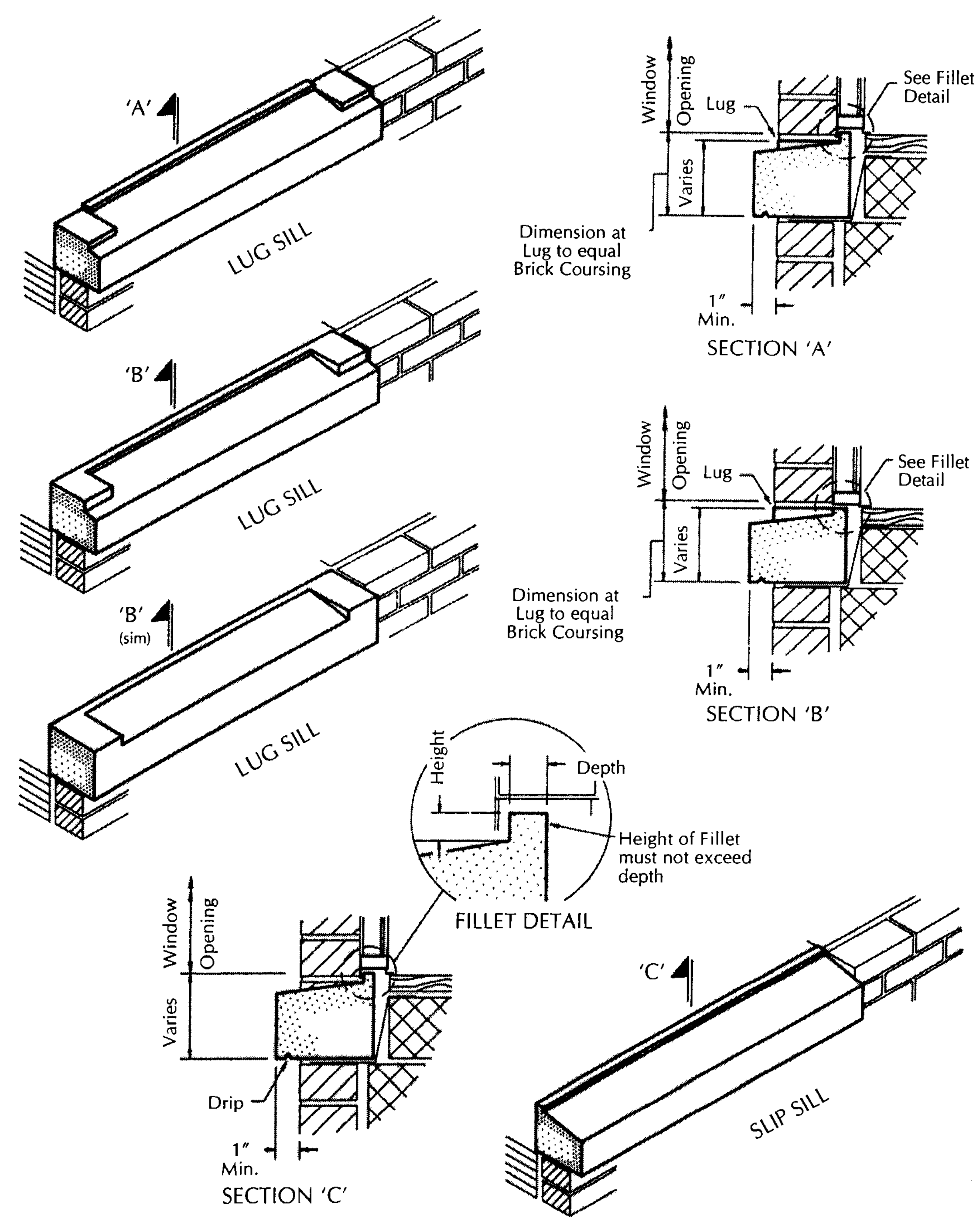
There should be a minimum of two anchor straps per stone and sufficient brick ties in accordance with the recommendations of your Engineer. The Brick Institute of America suggests one brick tie for each 2-2/3 sq. foot of wall area to tie back plain veneer.

Sheathing must be securely attached to both sides of the studs. Sheathing must be rigid and properly attached for it to be effective.



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3.9.4 Typical Lug and Slip Sill Details



By permission, Cast Stone Institute, Lebanon, PA.

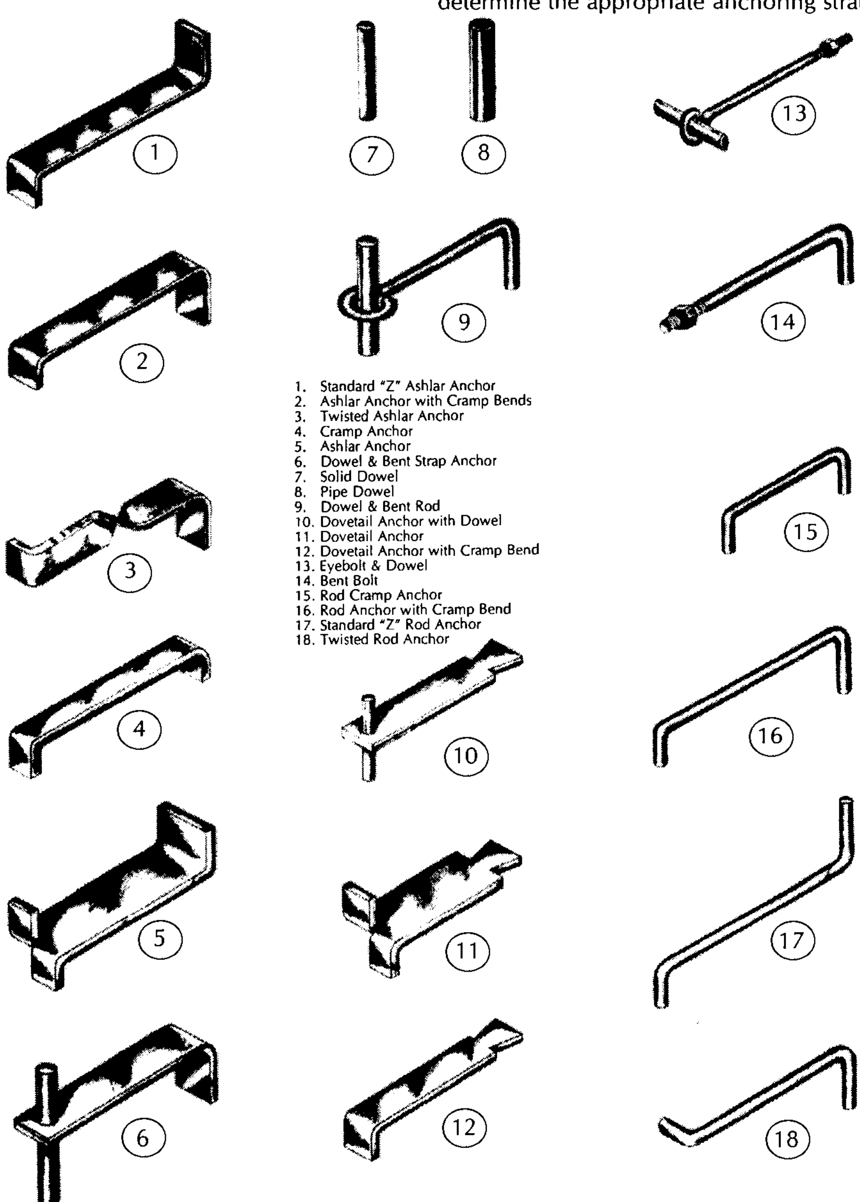
3.9.5 Anchors for Cast Stone Products

Standard masonry anchors are preferred over embedded hardware for use with Cast Stone. They are reliable, time-tested, and commercially available, need not be specially fabricated and afford great flexibility in meeting jobsite conditions.

Non-corrosive type anchors should be used for all anchoring. Stainless steel Type 302 or 304 are the standard type used in this class of work.

Typical sizes shown are 1/8" x 1" straps, 1/4" rods and 1/2" dowels. Dowel holes for 1/2" or 3/4" dowels are usually 1" diameter filled completely with mortar during setting. Anchor slots are typically 3/4" wide and similarly are filled with mortar.

Typical details are not universal. The Cast Stone Institute® strongly recommends that designers consult with the project engineer and Cast Stone Institute® producer member in the early stages of design to determine the appropriate anchoring strategy.



By permission, Cast Stone Institute, Lebanon, PA.

3.9.6 Control Joint Details

When installed properly, Cast Stone coping is the best type of moisture protection for a masonry wall. Coping provides aesthetic treatment, bonds with the masonry and its relatively maintenance-free.

Coping should be thoroughly drenched with clear, potable water and then set in a full bed of mortar with the bed joint raked back 1/2" for gun-in of sealant. Head joints are left open to receive properly placed backer rod, primer and sealant. The backer rod should be placed parallel to the wash of the coping.

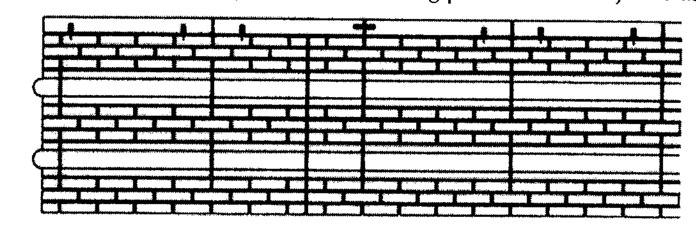
Bridge coping over control joints to maximize their effectiveness and use an elastic joint as shown. All coping should have a minimum 1/2" wash to control water runoff.

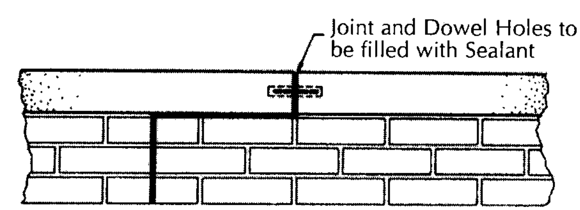
For maximum economy, either maintain consistent spacing between control joints to permit modularity in lengths of masonry bound stones or allow a special length stone at each control joint.

Where 1"+ projections occur, drips should be provided to break the return of water to the wall.

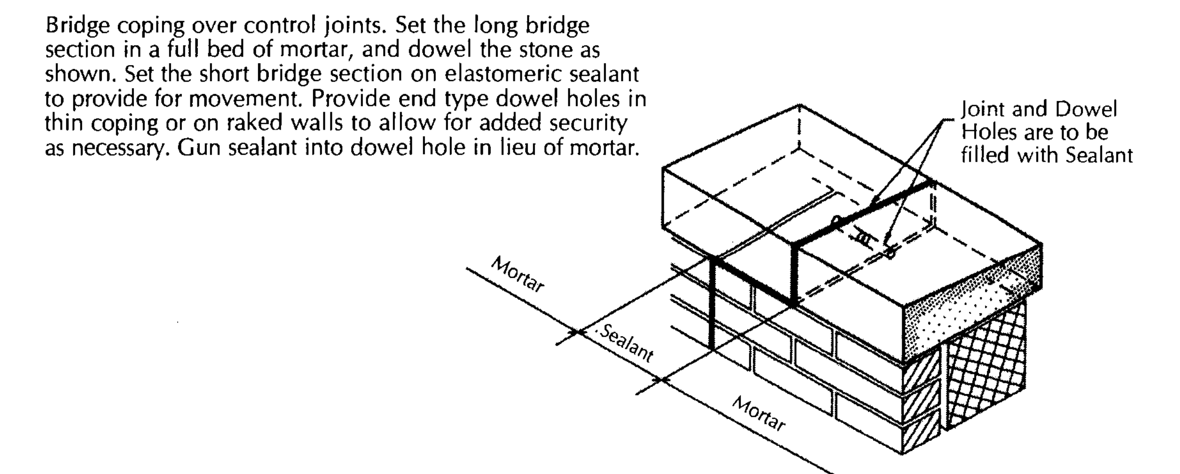
CONTROL JOINTS

For optimum economy with trim stones, maintain the maximum quantity of lengths at the same size; use a short or long piece to control joints as shown:





Bridge coping over control joints. Set the long bridge section in a full bed of mortar, and dowel the stone as shown. Set the short bridge section on elastomeric sealant to provide for movement. Provide end type dowel holes in thin coping or on raked walls to allow for added security as necessary. Gun sealant into dowel hole in lieu of mortar.



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3.9.7 Stone Dimensions, Tolerances

STONE DIMENSIONS

(Course Dimension less 3/8″ joint)

COURSE	Stone Coursing with Brick		Stone Coursing with Concrete Block	
	Modular Brick	2 5/8″ Brick	7 5/8″ Block	3 5/8″ Block
1	2 1/4″	2 5/8″	7 5/8″	3 5/8″
2	5″	5 5/8″	1′3 5/8″	7 5/8″
3	7 5/8″	8 5/8″	1′11 5/8″	11 5/8″
4	10 1/4″	11 5/8″	2′7 5/8″	1′3 5/8″
5	1′1″	1′2 5/8″	3′3 5/8″	1′7 5/8″
6	1′3 5/8″	1′5 5/8″	3′11 5/8″	1′11 5/8″
7	1′6 1/4″	1′8 5/8″	4′7 5/8″	2′3 5/8″
8	1′8 15/16″	1′11 5/8″	5′3 5/8″	2′7 5/8″
9	1′11 5/8″	2′2 5/8″	5′11 5/8″	2′11 5/8″
10	2′2 1/4″	2′5 5/8″	6′7 5/8″	3′3 5/8″
11	2′5″	2′8 5/8″	7′3 5/8″	3′7 5/8″
12	2′7 5/8″	2′11 5/8″	7′11 5/8″	3′11 5/8″
13	2′10 1/4″	3′2 5/8″	8′7 5/8″	4′3 5/8″
14	3′1″	3′5 5/8″	9′3 5/8″	4′7 5/8″
15	3′3 5/8″	3′8 5/8″	9′11 5/8″	4′11 5/8″
16	3′6 1/4″	3′11 5/8″	10′7 5/8″	5′3 5/8″
17	3′8 15/16″	4′2 5/8″	11′3 5/8″	5′7 5/8″
18	3′11 5/8″	4′5 5/8″	11′11 5/8″	5′11 5/8″
19	4′2 1/4″	4′8 5/8″	12′7 5/8″	6′3 5/8″
20	4′5″	4′11 5/8″	13′3 5/8″	6′7 5/8″
21	4′7 5/8″	5′2 5/8″	13′11 5/8″	6′11 5/8″
22	4′10 1/4″	5′5 5/8″	14′7 5/8″	7′3 5/8″
23	5′1″	5′8 5/8″	15′3 5/8″	7′7 5/8″
24	5′3 5/8″	5′11 5/8″	15′11 5/8″	7′11 5/8″
25	5′6 1/4″	6′2 5/8″	16′7 5/8″	8′3 5/8″
26	5′8 15/16″	6′5 5/8″	17′3 5/8″	8′7 5/8″
27	5′11 5/8″	6′8 5/8″	17′11 5/8″	8′11 5/8″
28	6′2 1/4″	6′11 5/8″	18′7 5/8″	9′3 5/8″
29	6′5″	7′2 5/8″	19′3 5/8″	9′7 5/8″
30	6′7 5/8″	7′5 5/8″	19′11 5/8″	9′11 5/8″
31	6′10 1/4″	7′8 5/8″	20′7 5/8″	10′3 5/8″
32	7′1″	7′11 5/8″	21′3 5/8″	10′7 5/8″
33	7′3 5/8″	8′2 5/8″	21′11 5/8″	10′11 5/8″
34	7′6 1/4″	8′5 5/8″	22′7 5/8″	11′3 5/8″
35	7′8 15/16″	8′8 5/8″	23′3 5/8″	11′7 5/8″
36	7′11 5/8″	8′11 5/8″	23′11 5/8″	11′11 5/8″
37	8′2 1/4″	9′2 5/8″	24′7 5/8″	12′3 5/8″
38	8′5″	9′5 5/8″	25′3 5/8″	12′7 5/8″
39	8′7 5/8″	9′8 5/8″	25′11 5/8″	12′11 5/8″
40	8′10 1/4″	9′11 5/8″	26′7 5/8″	13′3 5/8″
41	9′1″	10′2 5/8″	27′3 5/8″	13′7 5/8″
42	9′3 5/8″	10′5 5/8″	27′11 5/8″	13′11 5/8″
43	9′6 1/4″	10′8 5/8″	28′7 5/8″	14′3 5/8″
44	9′8 15/16″	10′11 5/8″	29′3 5/8″	14′7 5/8″
45	9′11 5/8″	11′2 5/8″	29′11 5/8″	14′11 5/8″

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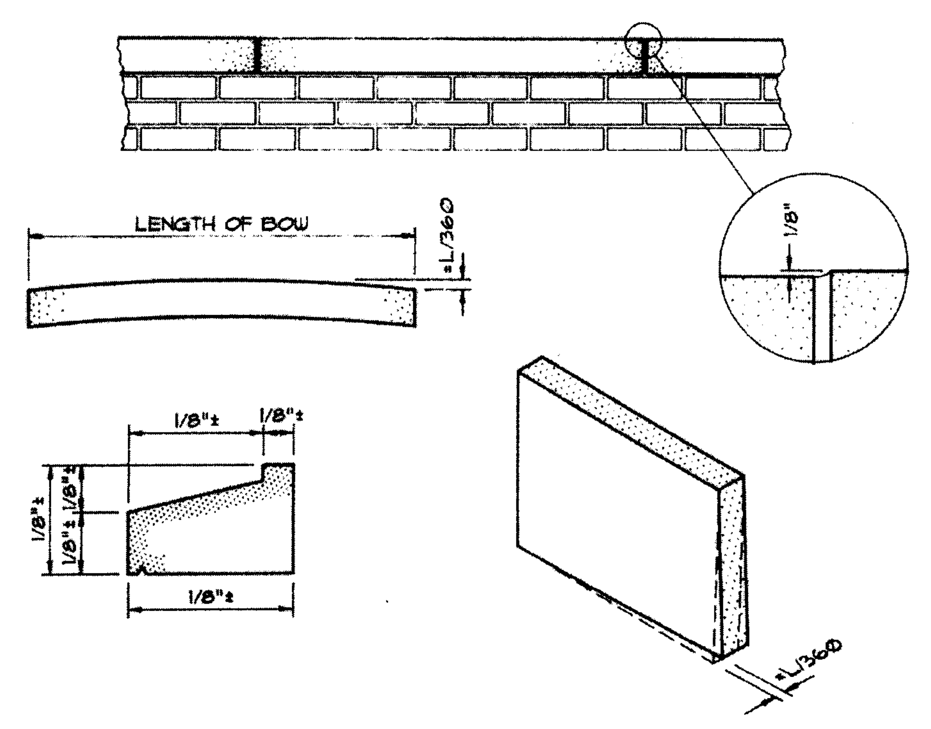
3.9.7 Stone Dimensions, Tolerances (Continued)

TOLERANCES

Tolerances dimensional tolerances for Cast Stone are the numerically greater of plus or minus 1/8″ and length/360. This applies to all sectional dimensions: length, twist, square and camber.

Dowel hole and insert locations in the formed sides of pieces can be cast fairly accurately, within 1/8″. Additional tolerance, totaling 3/8″, must be allowed when they are located in the back or unformed side.

When assessing individual stones for tolerance, the setting tolerances of plus or minus 1/8″ (allowable out of plane from adjacent unit) must also be taken into consideration as shown. This tolerance also applies to flashing grooves, false joints and similar reliefs.



By permission, Cast Stone Institute, Lebanon, PA.

3.10.0 Curtain Wall Construction

A curtain wall is a building façade that doesn't carry any dead load from the building other than its own dead load. The curtain wall is attached to the exterior of the building through connections at the floor or at the building's structural columns. The curtain wall is designed to resist air and water penetration, wind forces, seismic events, and its own dead load force.

3.11.0 Roofing Materials

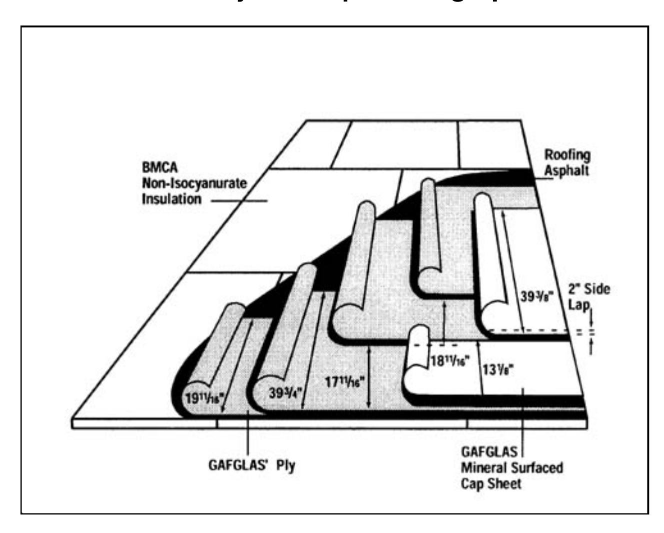
Roofing materials include granule surfaced rolled roofing; built-up roofing; liquid applied membrane; single-ply membrane; metal, ceramic, and "green roofs," each of which relate to function, aesthetics, and cost-effectiveness

3.11.1 Built-Up Roof (BUR)

A built-up roof is a roofing system consisting of multiple layers of fiberglass reinforced ply sheets (felts) alternating with hot, mopped on bitumen installed over insulation. This type of roofing system is applicable to flat or low-slope applications.

The BUR roofing materials are protected from solar radiation and abrasion created by rain or snow by embedding gravel in the bitumen or applying a granular surfaced cap sheet.

3.11.1.1 Three-Ply Built-up Roofing Specification



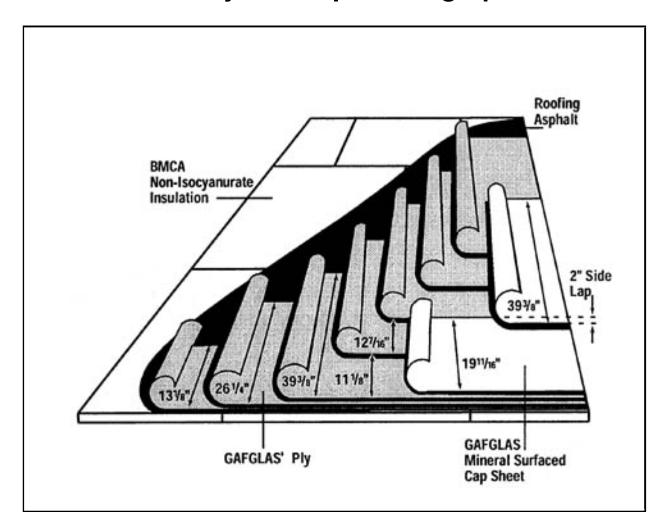
GENERAL
Safety: Refer to Section Section 1.06.
DO NOT BEGIN INSTALLATION
UNTIL THIS INFORMATION IS READ,
UNDERSTOOD AND IMPLEMENTED.

MATERIALS

Material Requirements per 100 sq. ft.:
Asphalt (per ply) . . . . . . .25 lbs. (1.22 kg/m^2)
Ply Sheets . . . . .2 plies
Cap Sheets . . . . .1 ply
Surfacing (if applicable)

Source: GAF Materials Corporation.

3.11.1.2 Four-Ply Built-Up Roofing Specification



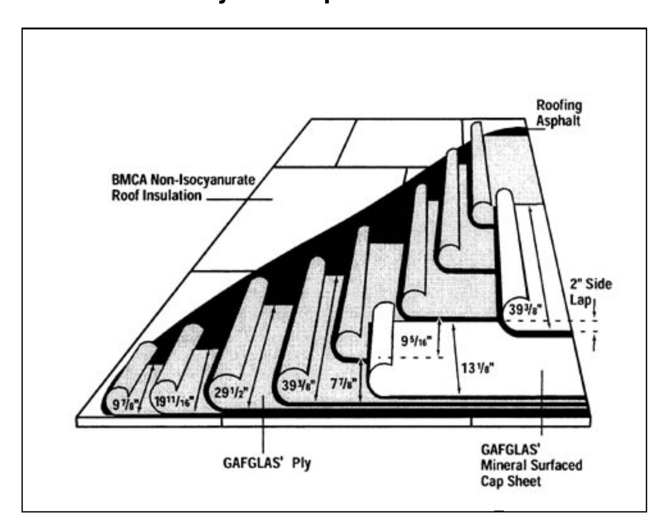
GENERAL
Safety: Refer to Section Section 1.06.
DO NOT BEGIN INSTALLATION
UNTIL THIS INFORMATION IS READ,
UNDERSTOOD AND IMPLEMENTED.

MATERIALS

Material Requirements per 100 sq. ft.:
Insulation (Non-Isocyanurate)
Asphalt (per ply) . . . . . . .25 lbs. (1.22 kg/m^2)
Ply sheets . . . . .3 plies
Cap sheet . . . . .1 ply

Source: GAF Materials Corporation.

3.11.1.3 Five-Ply Built-up Roof Installed over Insulated Deck



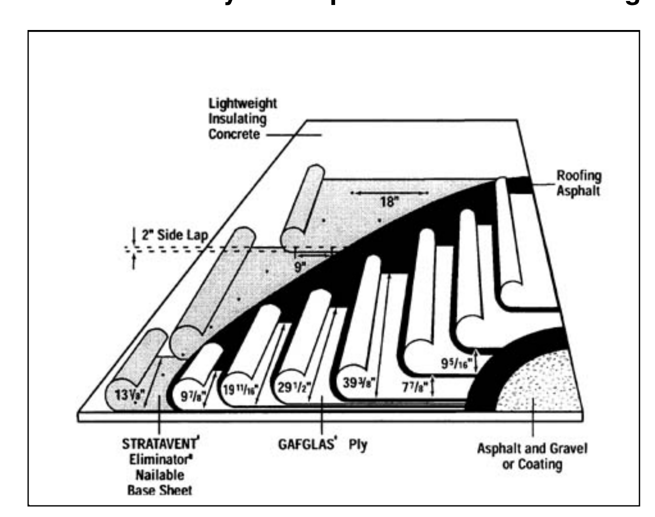
GENERAL
Safety: Refer to Section Section 1.06.
DO NOT BEGIN INSTALLATION
UNTIL THIS INFORMATION IS READ,
UNDERSTOOD AND IMPLEMENTED.

MATERIALS

Material Requirements per 100 sq. ft.:
Insulation (Non-Isocyanurate)
Asphalt (per ply) . . . . . . .25 lbs. (1.22 kg/m^2)
Ply Sheets . . . . .4 plies
Cap Sheet . . . . .1 ply

Source: GAF Materials Corporation.

3.11.1.4 Five-Ply Built-up Roof Installed over Lightweight Concrete Deck



GENERAL
Safety: Refer to Section Section 1.06.
DO NOT BEGIN INSTALLATION
UNTIL THIS INFORMATION IS READ,
UNDERSTOOD AND IMPLEMENTED.

MATERIALS

Material Requirements per 100 sq. ft.:
Asphalt (per ply) . . . . . . .25 lbs. (1.22 kg/m^2)
Base Sheet . . . . .1 ply
Ply Sheets . . . . .4 plies
Surfacing

Source: GAF Materials Corporation.

3.12.0 Single-Ply Membrane Roofs

Single-ply membrane roofs are manufactured from ethylene propylene diene monomer (EPDM) or polyvinyl chloride (PVC) or a thermoplastic polyolefin material referred to as TPO.

There are three basic types of installation:

1. *Fully adhered.* The membranes are attached to one another and the substrate with a water- or solvent-based adhesive.
2. *Mechanically fastened*. The membranes are attached to the substrate with manufacturer-approved fasteners.
3. *Loosely laid*. The membrane is secured to the substrate at the roof edge perimeter and around all roof penetrations with smooth surface, river rock, or concrete pavers.

3.12.1 EPDM

Both reinforced and nonreinforced single-ply membrane is available in various mil thicknesses per the *EPDM Membrane Selector Guide* published by Johns Manville.

JM EPDM Membrane Selector Guide

Description	Product	ASTM	Thickness	Color	Sizes Width x Length	Area per Roll	Weight	Specifications: Mechanically Fastened	Specifications: Fully Adhered	Specifications: Ballasted	Guarantees: Mechanically Fastened	Guarantees: Fully Adhered	Guarantees: Ballasted
Polyester reinforced, factory cleaned EPDM for use in ballasted, mechanically fastened, and fully adhered roofing systems.	JM EPDM 45R	D 4637	45 mil	Black	10' x 100' (3.05 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	300 lb (136.08 kg)	SE4RM-(T)	SE4RA-(T)	SE4RB-(T)	5, 10, or 15 yr NDL	5, 10, or 15 yr NDL	5, 10, or 15 yr NDL
	JM EPDM 60R		60 mil		7' x 100' (2.13 m x 30.48 m)	700 ft^2 (65.06 m^2)	276.5 lb (125.42 kg)	SE6RM-(T)	SE6RA-(T)	SE6RB-(T)	5, 10, or 15 yr NDL	5, 10, 15, or 20 yr NDL	5, 10, or 15 yr NDL
					10' x 100' (3.05 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	395 lb (179.17 kg)						
Nonreinforced, fire rated EPDM for use in fully adhered and ballasted systems. For use as a flashing in some applications	JM EPDM 45 FR		45 mil		10' x 50' (3.05 m x 15.24 m)	500 ft^2 (46.45 m^2)	179 lb (81.23 kg)	N/A	SE4A-(T)	SE4B-(T)	N/A	5 or 10 yr NDL	5 or 10 yr NDL
					10' x 100' (3.05 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	335 lb (151.75 kg)						
					20' x 50' (6.1 m x 15.24 m)	1,000 ft^2 (92.90 m^2)	335 lb (151.75 kg)						
					20' x 100' (6.1 m x 30.48 m)	2,000 ft^2 (185.81 m^2)	659 lb (299.11 kg)						
					30' x 100' (9.14 m x 30.48 m)	3,000 ft^2 (278.71 m^2)	970 lb (440.16 kg)						
					40' x 100' (12.19 m x 30.48 m)	4,000 ft^2 (371.61 m^2)	1,281 lb (581.22 kg)						
	JM EPDM 60 FR		60 mil		10' x 50' (3.05 m x 15.24 m)	500 ft^2 (46.45 m^2)	231 lb (104.74 kg)	N/A	SE6A-(T)	SE6B-(T)	N/A	5, 10, 15, or 20 yr NDL	5, 10, or 15 yr NDL
					10' x 100' (3.05 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	438 lb (198.77 kg)						
					15' x 100' (4.57 m x 30.48 m)*	1,500 ft^2 (139.35 m^2)	677 lb (307.11 kg)						
					20' x 50' (6.1 m x 15.24 m)	1,000 ft^2 (92.90 m^2)	438 lb (198.77 kg)						
					20' x 100' (6.1 m x 30.48 m)	2,000 ft^2 (185.81 m^2)	867 lb (393.14 kg)						
					30' x 100' (9.14 m x 30.48 m)	3,000 ft^2 (278.71 m^2)	1281 lb (581.22 kg)						
	JM EPDM 90 FR		90 mil		10' x 100' (3.05 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	625 lb (283.65 kg)	N/A	SE9A-(T)	SE9B-(T)	N/A	5, 10, 15, or 20 yr NDL	5, 10, or 15 yr NDL

Source: Johns Manville, Denver, Colorado.

3.12.2 PVC Reinforced Single-Ply Membrane

PVC reinforced single-ply membrane is available in thicknesses ranging from 50 to 103 mil, per the PVC Membrane Guide published by Johns Manville.

JM PVC Membranes

Description	Product	ASTM	Thickness	Color			Sizes	Area per Roll	Weight	Specifications		Guarantees
				White	Grey	Sandstone	Width x Length			Mechanically Fastened	Fully Adhered	Mechanically Fastened or Fully Adhered
Thermoplastic, polyester reinforced membrane. Manufactured using an ultraviolet-resistant PVC (polyvinyl chloride) and an Elvaloy KEE (ketone ethylene ester) formulation.	JM PVC 50	D 4464, Type III	50 mil	X	X	X	6.5' x 100' (1.98 m x 30.48m)	650 ft² (60.39 m²)	220 lb (99.79 kg)	SP5RM	SP5RA	5, 10 or 15 yr NDL
							3.25' x 100' (1 m x 30.48m)	325 ft² (30.19 m²)	111 lb (50.35 kg)			
				X	*	*	10' x 100' (3.05 m x 30.48 m)	1,000 ft² (92.90 m²)	338 lb (153.31 kg)			
							5' x 100' (1.52 m x 30.48 m)	500 ft² (46.45 m²)	169 lb (76.66 kg			
	JM PVC 60		60 mil	X	X	X	6.5' x 100' (1.98 m x 30.48m)	650 ft² (60.39 m²)	261 lb (118.39 kg)	SP6RM	SP6RA	5, 10, 15, or 20 yr NDL
							3.25' x 100' (1 m x 30.48m)	325 ft² (30.19 m²)	131 lb (59.42 kg)			
				X	*	*	10' x 100' (3.05 m x 30.48 m)	1,000 ft² (92.90 m²)	402 lb (182.34 kg)			
							5' x 100' (1.52 m x 30.48 m)	500 ft² (46.45 m²)	201 lb (91.17 kg)			
	JM PVC 80		80 mil	X	*	*	6.5' x 75' (1.98 m x 30.48 m)	488 ft² (45.34 m²)	261 lb (118.39 kg)	SP8RM	SP8RA	5, 10, 15, or 20 yr NDL
							3.25' x 75' (1 m x 22.86 m)	244 ft² (22.67 m²)	131 lb (59.42 kg)			
	JM PVC 50 Fleece Backed		73 mil	X	*	*	6.33' x 90' (1.93 m x 27.43 m)	570 ft² (52.95 m²)	209 lb (94.80 kg)	SP5PM	SP5PA	5, 10 or 15 yr NDL
	JM PVC 60 Fleece Backed		88 mil	X	*	*	6.33' x 90' (1.93 m x 27.43 m)	570 ft² (52.95 m²)	244 lb (110.68 kg)	SP6PM	SP6PA	5, 10, 15 or 20 yr NDL
	JM PVC 80 Fleece Backed		103 mil	X	*	*	6.33' x 90' (1.93 m x 27.43 m)	570 ft² (52.95 m²)	320 lb (145.15 kg)	SP8PM	SP8PA	5, 10, 15 or 20 yr NDL

Source: Johns Manville, Denver, Colorado.

3.12.3 TPO Reinforced Single-Ply Membrane

TPO reinforced single-ply membrane is available in thicknesses ranging from 45 to 80 mil per the TPO Membrane Selector Guide published by Johns Manville.

JM TPO Membrane Selector Guide

Description	Product	ASTM	Thickness	Color			Sizes	Area per Roll	Weight	Specifications		Guarantees
				White	Grey	Tan	Width x Length			Mechanically Fastened	Fully Adhered	Mechanically Fastened and Fully Adhered
Thermoplastic, polyester reinforced membrane manufactured using an ultraviolet-resistant TPO (thermoplastic polyolefin) formulation.	JM TPO-45	D 6878	45 mil	X	X	X	4' x 100' (1.22 m x 30.48 m)	400 ft^2 (37.16 m^2)	84 lb (38.10 kg)	ST4RM	ST4RA	5 or 10 yr NDL
				X			6.16' x 100' (1.88 m x 30.48 m)	616 ft^2 (57.23 m^2)	131 lb (59.42 kg)			
				X	X	X	8' x 100' (2.44 m x 30.48 m)	800 ft^2 (74.32 m^2)	168 lb (76.20 kg)			
				X			10'x 100' (3.04 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	210 lb (95.25 kg)			
				X			12.33'x 100' (3.76 m x 30.48 m)	1,233 ft^2 (114.55 m^2)	259 lb (117.48 kg)			
	JM TPO-60		60 mil	X	X	X	4'x 100' (1.22 m x 30.48 m)	400 ft^2 (37.16 m^2)	112 lb (50.80 kg)	ST6RM	ST6RA	5, 10, 15, or 20 yr NDL
				X			6.16' x 100' (1.88 m x 30.48 m)	616 ft^2 (57.23 m^2)	181 lb (82.10 kg)			
				X	X	X	8' x 100' (2.44 m x 30.48 m)	800 ft^2 (74.32 m^2)	232 lb (105.23 kg)			
				X			10'x 100' (3.04 m x 30.48 m)	1,000 ft^2 (92.90 m^2)	290 lb (131.54 kg)			
				X			12.33'x 100' (3.76 m x 30.48 m)	1,233 ft^2 (114.55 m^2)	358 lb (162.39 kg)			
	JM TPO-72		72 mil	X			4'x 75' (1.22 m x 22.86 m)	300 ft^2 (27.87 m^2)	102 lb (46.27 kg)	ST7RM	ST7RA	5, 10, 15, or 20 yr NDL
				X			8'x 75' (2.44 m x 22.86 m)	600 ft^2 (55.74 m^2)	204 lb (92.53 kg)			
	JM TPO-80		80 mil	X			4'x 75' (1.22 m x 22.86 m)	300 ft^2 (27.87 m^2)	114 lb (51.71 kg)	ST8RM	ST8RA	5, 10, 15, or 20 yr NDL
				X			8'x 75' (2.44 m x 22.86 m)	600 ft^2 (55.74 m^2)	228 lb (103.42 kg)			

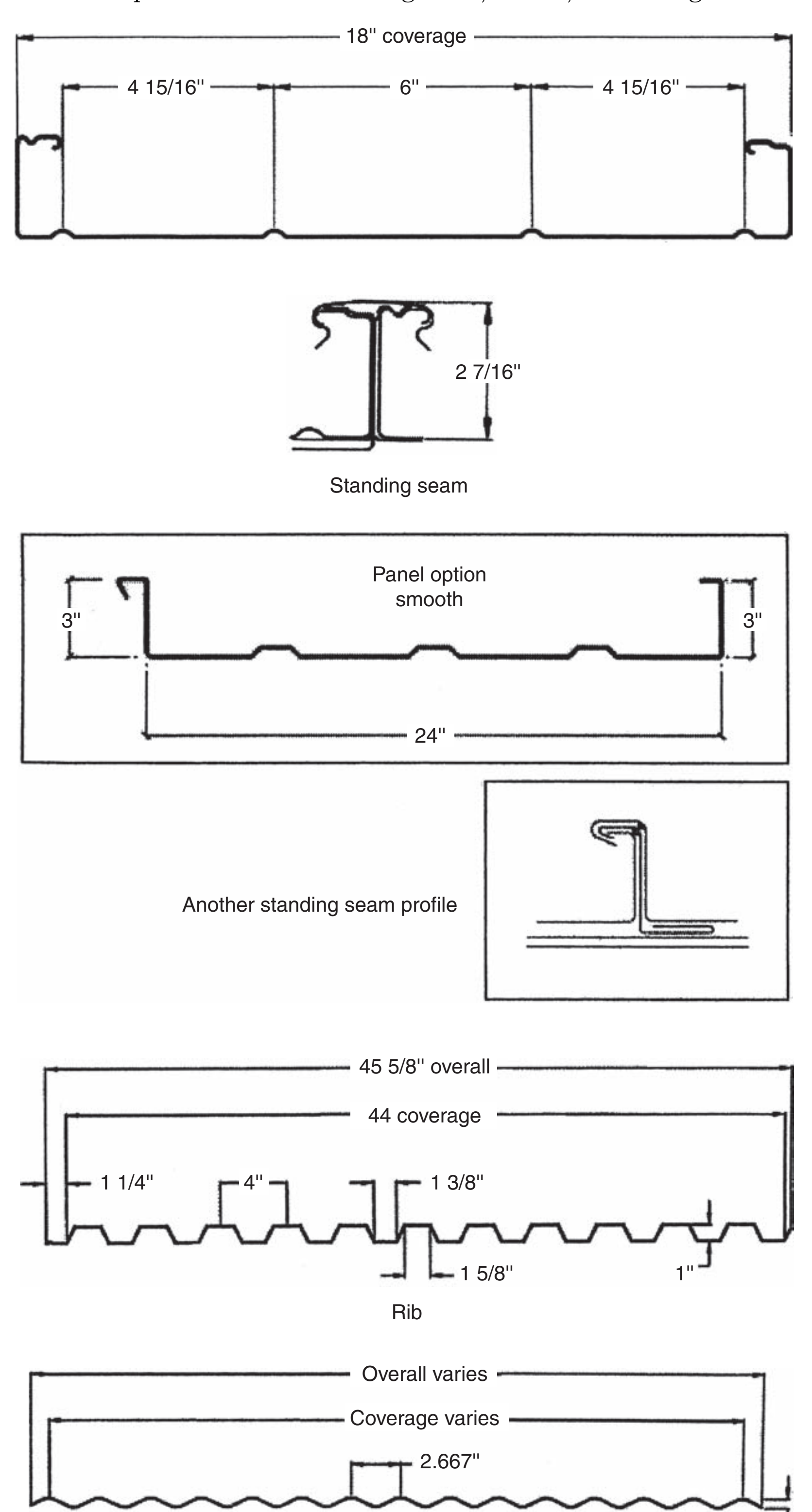
Source: Johns Manville, Denver, Colorado.

3.13.0 Metal Roofs

Generally coated with Kynar®, a non-chalking, long life material is available in a variety of profiles.

3.13.1 Steel, Aluminum Metal Roof Profiles

Metal roof profiles come in standing seam, ribbed, and corrugated forms.

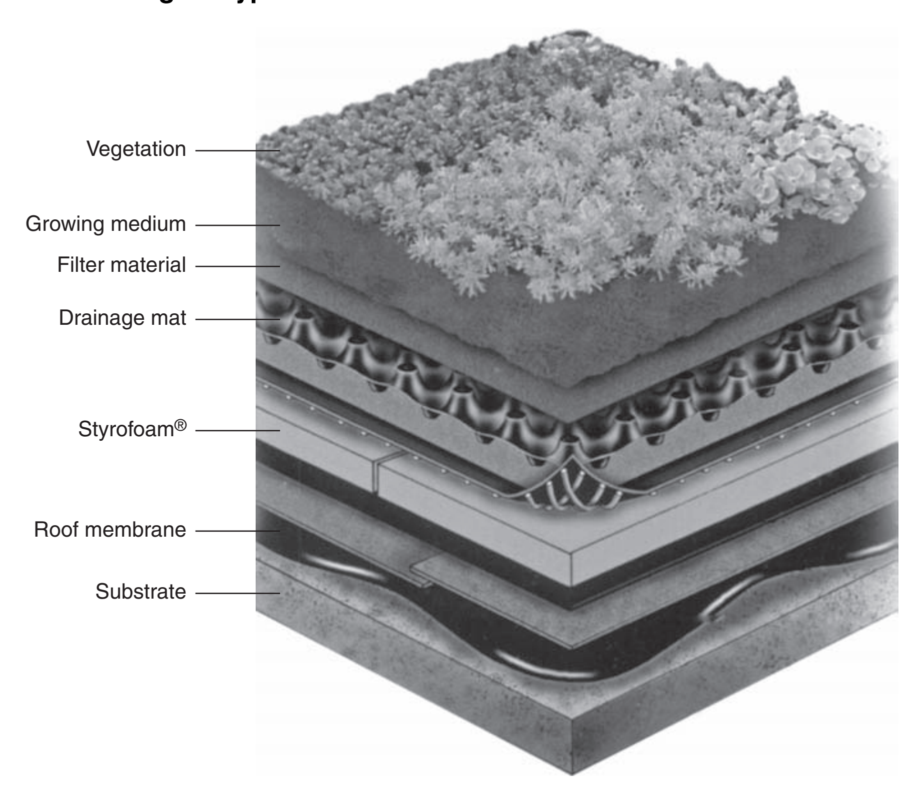


3.14.0 Green Roofs

Green roofs, which can be applied to both flat and some sloped roofs, are environmentally "friendly" and create the following benefits for building owners:

- They reduce storm water management.
- They offer energy efficiency.
- They effectively absorb external noises.
- They process airborne toxins.
- They reoxygenate the environment.
- They are wildlife-friendly.

3.14.1 Section through a Typical Green Roof

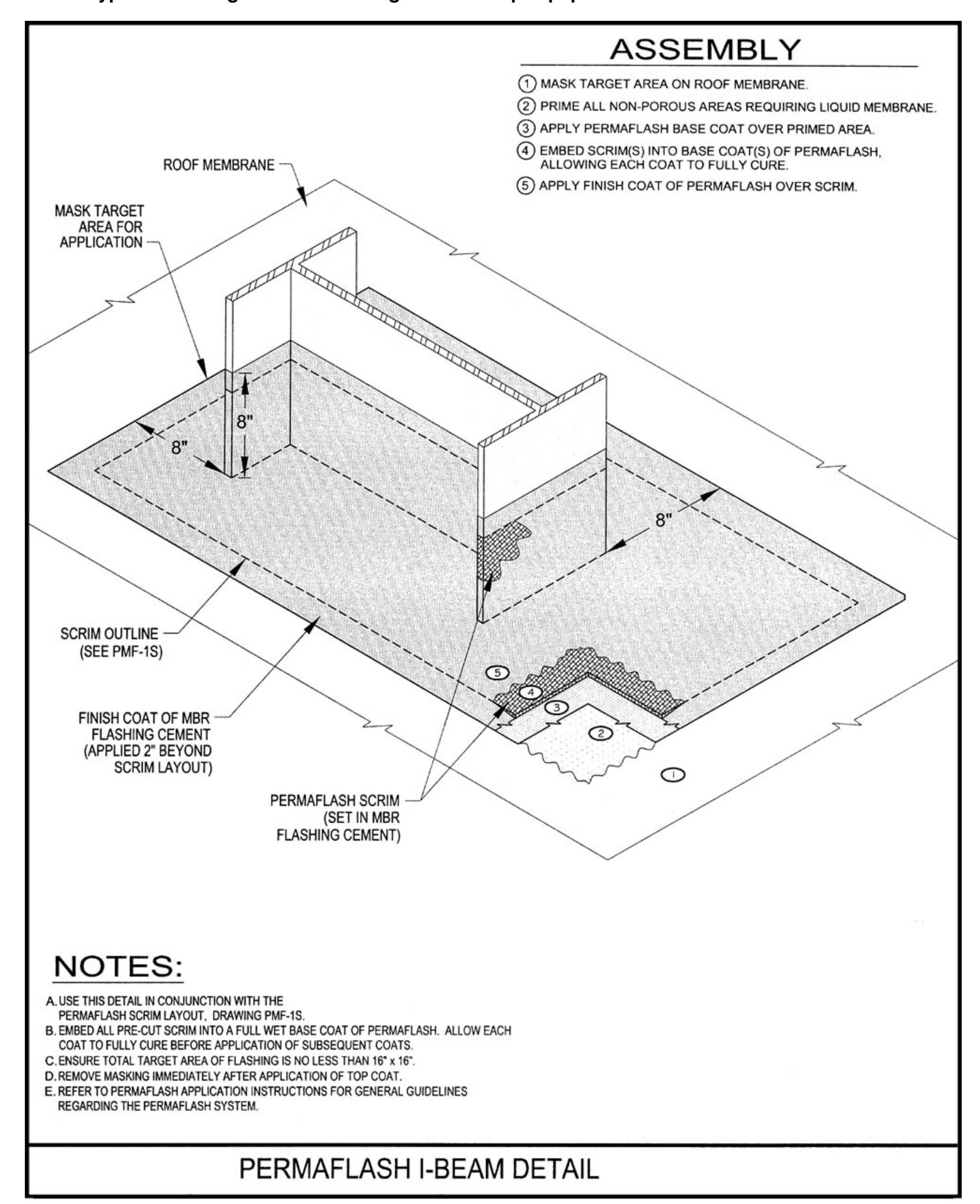


Source: American Hydrotech, Inc., Chicago, Illinois.

3.15.0 Roof Flashings

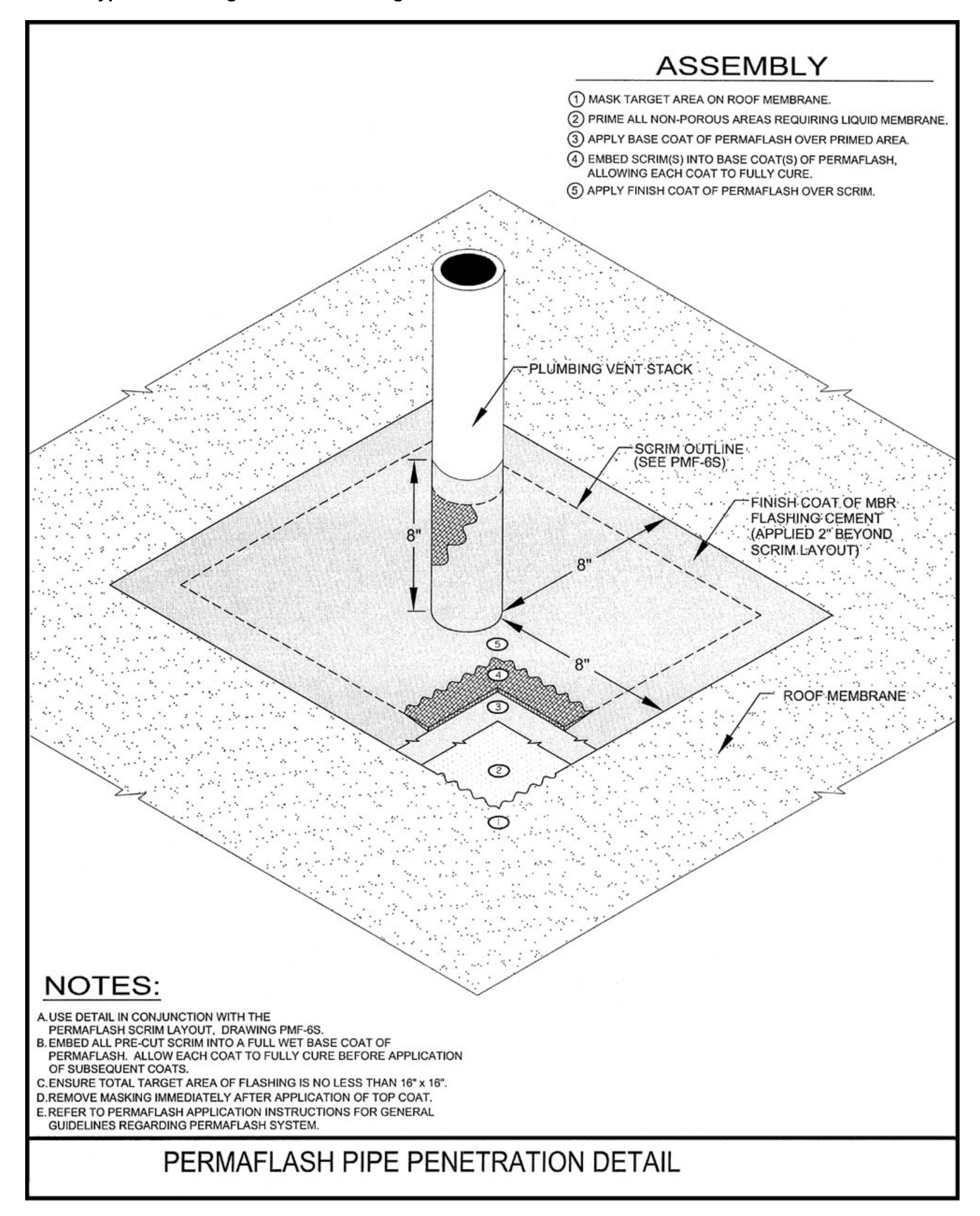
Roof flashings are required for either build-up roofs or single-ply membrane roofs to prevent water infiltration into the building from various roof penetrations such as vent lines, rain leaders, roof hatches, and dunnage to support rooftop equipment. Flashings are made from a variety of materials: galvanized steel, aluminum, copper, zinc, lead, and nonmetallic materials.

3.15.1 Typical Flashing Details—Dunnage for Rooftop Equipment



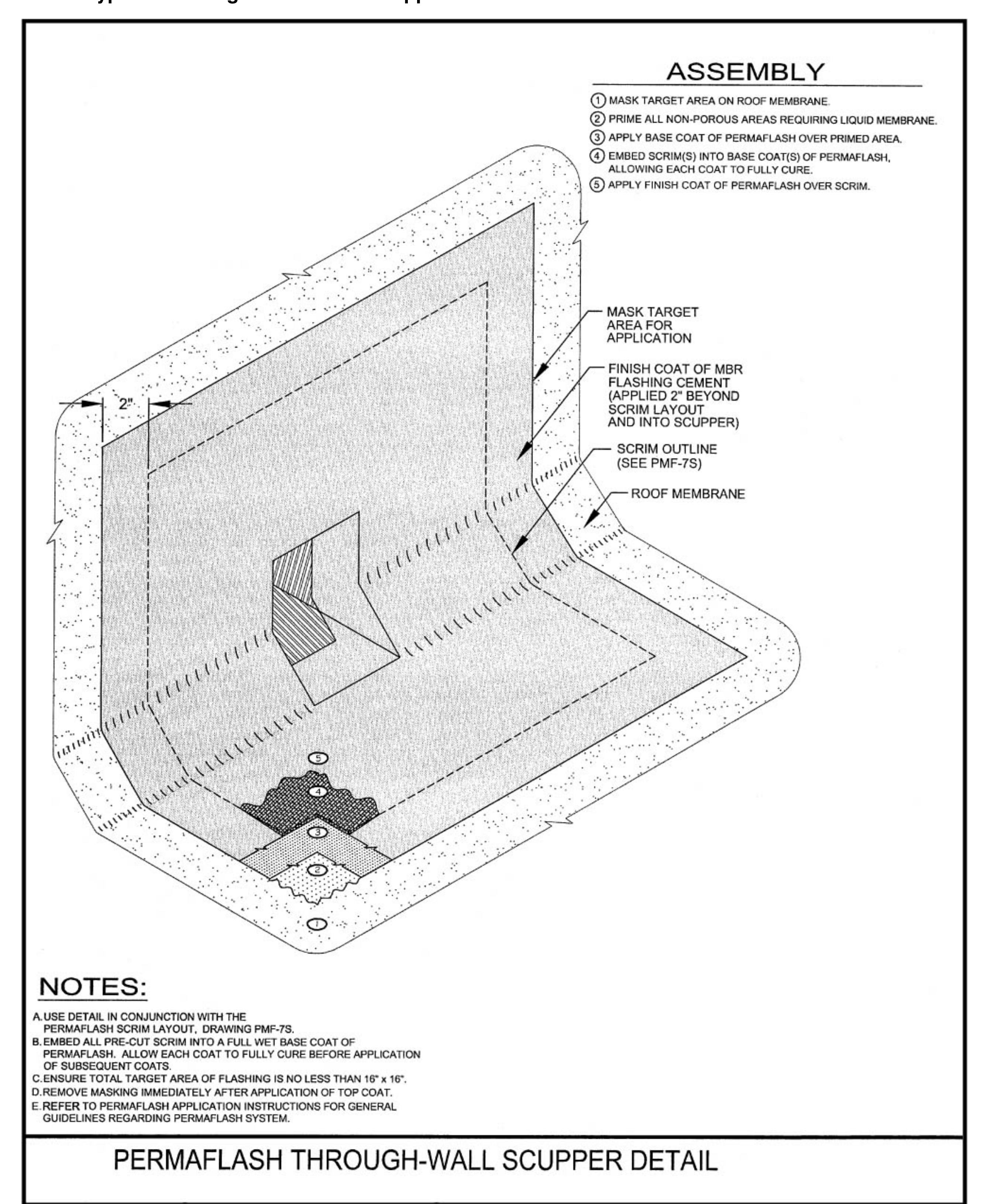
Source: Johns Manville, Denver, Colorado.

3.15.2 Typical Flashing Detail—Plumbing Vents and Stacks



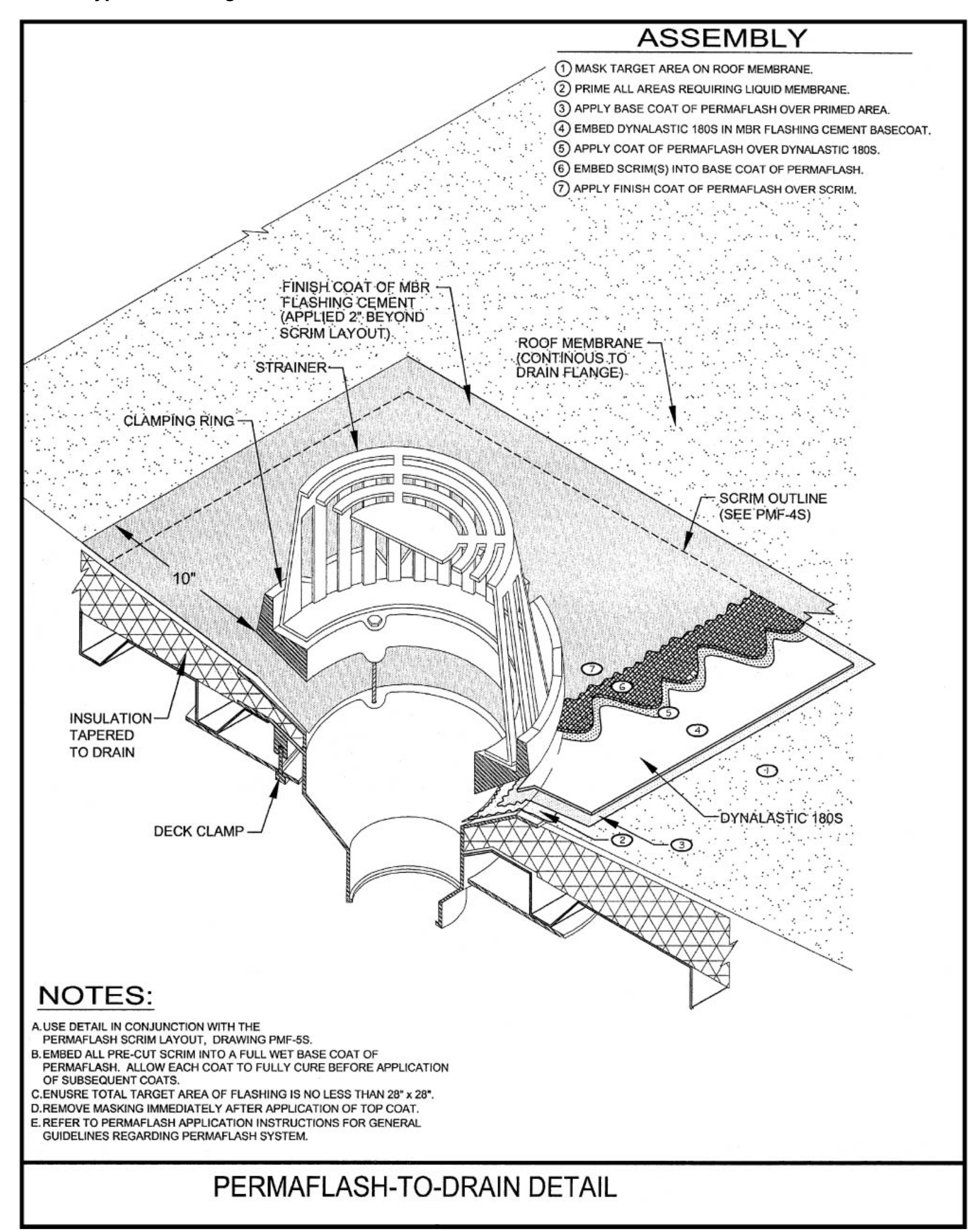
Source: Johns Manville, Denver, Colorado.

3.15.3 Typical Flashing Detail—Roof Scupper



Source: Johns Manville, Denver, Colorado.

3.15.4 Typical Flashing—Roof Drain



Source: Johns Manville, Denver, Colorado.

3.16.0 Roof and Exterior Wall Insulation

There are three designations to express the insulating value of a material: R, U, and C values. The R value is the insulating value of a material; the higher the R value, the better the insulating qualities of the material. The U value is a measure of heat loss through a material; so the lower the U value, the lower the heat loss. The C value is a measure of thermal conductance of the material and is actually the reciprocal of the R value.

3.16.1 R and C Values for Various Types of Roof Deck Insulation

Material	Thickness In Inches	C-Value	R-Value
Metal	N/A	0.000	0.00
Concrete	1.0	3.333	0.30
Gypsum	1.0	1.667	0.60
Wood	1.0	1.099	0.91
Tectum	1.0	0.500	2.00
Inside Air Film	N/A	1.087	0.92
Outside Air Film - Summer	N/A	4.000	0.25
Outside Air Film - Winter	N/A	5.882	0.17
Vapor Retarders	N/A	0.000	0.00
BUR Gravel	N/A	2.941	0.34
BUR Smooth	N/A	4.167	0.24
Fiberboard	1.0	0.360	2.78
Perlite	1.0	0.360	2.78
Phenolic Foam*	1.0	0.120	8.30
Fiber Glass	1.0	0.256	3.90
Polyisocyanurate	1.0	0.180	5.56
Polyisocyanurate Composite	1.5	0.240	4.17
Polystyrene Bead Board	1.0	0.280	3.57
Polystyrene Composite Board	1.5	0.301	3.32
Polystyrene - Expanded (EPS)**	1.0	0.260	3.85
Polystyrene - Extruded (XEPS)***	1.0	0.200	5.00
Sprayed Polyurethane Foam****	1.0	0.150	6.88
Cork	1.0	0.280	3.57

3.16.2 Determining the C Value

The C-value (C) is a measure of the Thermal Conductance of the material and is the reciprocal of R, or

$$C = \frac{1}{R}$$

C is determined only when the Thermal Conductivity (k) of a material is known.

$$C = \frac{k}{\text{Thickness In Inches}}$$

Thermal Conductivity is the measure of the amount heat that will be transmitted through a one inch (1") thick piece of homogeneous material, one square foot (1 $ft.^2$) in size, in one (1) hour, when there is a one degree Fahrenheit (1° F) temperature change. The equation for "k" is:

$$k = \frac{\text{BTU} * \text{inch}}{\text{sq. ft.} * \text{hour} * {}^\circ\text{F}}$$

Source: roofhelp.com.

3.16.3 Calculating R Values for Various Materials

Calculating Assembly Wall R-Value*

Formula: Assembly R-value = 1 / (Assembly U-value) = 1 / (U-studs x % + U-cavity x %)

Component	R-Value Studs	R-Value Cavity	Assembly R-Value
Wall - Outside Air Film	0.17	0.17	
Siding - Wood Bevel	0.80	0.80	
Plywood Sheathing - 1/2"	0.63	0.63	
3 1/2" Fiberglass Batt		11.00	
3 1/2" Stud	4.38		
1/2" Drywall	0.45	0.45	
Inside Air Film	0.68	0.68	
Percent for 16" o.c. + Additional studs	15%	85%	
Total Wall Component R-Values	**7.12**	**13.73**	
Wall Component U-Values	**0.1404**	**0.0728**	
Total Wall Assembly R-Value			**12.05**

* This example is just for wood frame construction. Steel studs are a more complicated calculation.

R-Value Table

Material	R/ Inch	R/ Thickness
Insulation Materials		
Fiberglass Batt	3.14-4.30	
Fiberglass Blown (attic)	2.20-4.30	
Fiberglass Blown (wall)	3.70-4.30	
Rock Wool Batt	3.14-4.00	
Rock Wool Blown (attic)	3.10-4.00	
Rock Wool Blown (wall)	3.10-4.00	
Cellulose Blown (attic)	3.13	
Cellulose Blown (wall)	3.70	
Vermiculite	2.13	
Autoclaved Aerated Concrete	1.05	
Urea Terpolymer Foam	4.48	
Rigid Fiberglass (> 4lb/ft3)	4.00	
Expanded Polystyrene (beadboard)	4.00	
Extruded Polystyrene	5.00	
Polyurethane (foamed-in-place)	6.25	
Polyisocyanurate (foil-faced)	7.20	
Construction Materials		
Concrete Block 4"		0.80
Concrete Block 8"		1.11
Concrete Block 12"		1.28
Brick 4" common		0.80
Brick 4" face		0.44
Poured Concrete	0.08	
Soft Wood Lumber	1.25	
2" nominal (1 1/2")		1.88
2x4 (3 1/2")		4.38
2x6 (5 1/2")		6.88
Cedar Logs and Lumber	1.33	

3.16.3 Calculating R Values for Various Materials (Continued)

Sheathing Materials		
Plywood	1.25	
1/4"		0.31
3/8"		0.47
1/2"		0.63
5/8"		0.77
3/4"		0.94
Fiberboard	2.64	
1/2"		1.32
25/32"		2.06
Fiberglass (3/4")		3.00
(1")		4.00
(1 1/2")		6.00
Extruded Polystyrene (3/4")		3.75
(1")		5.00
(1 1/2")		7.50
Foil-faced Polyisocyanurate (3/4")		5.40
(1")		7.20
(1 1/2")		10.80
Siding Materials		
Hardboard (1/2")		0.34
Plywood (5/8")		0.77
(3/4")		0.93
Wood Bevel Lapped		0.80
Aluminum, Steel, Vinyl (hollow backed)		0.61
(w/ 1/2" Insulating board)		1.80
Brick 4"		0.44
Interior Finish Materials		
Gypsum Board (drywall 1/2")		0.45
(5/8")		0.56
Paneling (3/8")		0.47
Flooring Materials		
Plywood	1.25	
(3/4")		0.93
Particle Board (underlayment)	1.31	
(5/8")		0.82
Hardwood Flooring	0.91	
(3/4")		0.68
Tile, Linoleum		0.05
Carpet (fibrous pad)		2.08
(rubber pad)		1.23
Roofing Materials		
Asphalt Shingles		0.44
Wood Shingles		0.97

3.16.3 Calculating R Values for Various Materials (Continued)

Windows		
Single Glass		0.91
w/storm		2.00
Double insulating glass (3/16") air space		1.61
(1/4" air space)		1.69
(1/2" air space)		2.04
(3/4" air space)		2.38
(1/2" w/ Low-E 0.20)		3.13
(w/ suspended film)		2.77
(w/ 2 suspended films)		3.85
(w/ suspended film and low-E)		4.05
Triple insulating glass		2.56
Doors		
Wood Hollow Core Flush (1 3/4")		2.17
Solid Core Flush (1 3/4")		3.03
Solid Core Flush (2 1/4")		3.70
Panel Door w/ 7/16" Panels (1 3/4")		1.85
Storm Door (wood 50% glass)		1.25
(metal)		1.00
Metal Insulating (2" w/ urethane)		15.00
Air Films		
Interior Ceiling		0.61
Interior Wall		0.68
Exterior		0.17
Air Spaces		
1/2" to 4" approximately		1.00
(1/4" air spaces)		
(1/2" air spaces)		3.23
Addition for tight fitting drapes or shades, or closed blinds		0.29

3.17.0 Albedo—A Measure of Roof Membrane Energy Efficiencies

Resistance to heat flow has been quantified by the use of "R" values—a means of measuring how well a substance or material resists the transmission of heat into a building in hot weather and how well it keeps heat in a building during cold weather. But when it comes to energy gained or lost through a roof assembly, another form of measurement is often used, and that measure is referred to as "albedo"—solar reflectance. Albedo measures how much of the solar energy striking a roof membrane surface is reflected.

Energy efficient roofing systems exhibit three qualities:

1. Good reflectance—albedo.
2. Sufficient insulation to resist the flow of heat into the structure.
3. Good emissivity—the ability of the roof surface to radiate the absorbed energy away from the structure rather than retaining it.

The following chart lists albedo and emissivity factors for selected surfaces:

Material	Albedo	Emissivity
Concrete	0.3	0.94
Red brick	0.3	0.90
Tar paper	0.05	0.93
White plaster	0.93	0.91
Bright galvanized iron	0.35	0.13
Bright aluminum foil	0.85	0.04
White pigment	0.85	0.96
White single-ply roofing	0.78	0.90

Section

4

Carpentry, Framing, Drywall, Engineered Wood Products

Contents

4.5.2.3 Metal Corner Bead, Bullnose Corner Bead, Metal Trim, Tear-Away Beads
4.5.2.4 Steel Framing Member Fasteners
4.5.2.5 Drywall Furring Channel
4.5.3 Structural Studs
4.5.3.1 Structural Gauges for Load Bearing, Curtain Wall Framing, and Track
4.5.4 Steel Floor Joists
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4.0.0 Wood Framing—Two Most Common Species

The two most common species for wood framing are southern pine; and western lumber-fir, hemlock-fir, and lodgepole and ponderosa pine.

4.1.0 Western Lumber Species—Base Values

This table shows base values for western dimensional lumber and adjustments to these base values.

Framing Lumber

BASE VALUES FOR WESTERN DIMENSION LUMBER[1]

Table **1**



Nominal Sizes: 2" to 4" thick by 2" and wider[2]

Use with appropriate Adjustments, Tables A through G

Grades described in *Western Lumber Grading Rules*, Sections 40.00, 41.00, 42.00 and 62.00. Also Stress-Rated Boards, see Section 30.60

Species or Group	Grade	Extreme Fiber Stress in Bending Single Member F_b	Tension Parallel to Grain F_t	Horizontal Shear[3] F_v	Compression Perpendicular $F_{c\perp}$	Compression Parallel to Grain F_c	Modulus of Elasticity E	Modulus of Elasticity E_{min}
Douglas Fir-Larch	Select Structural	1500	1000	180	625	1700	1,900,000	690,000
	No. 1 & Btr.	1200	800	180	625	1550	1,800,000	660,000
	No. 1	1000	675	180	625	1500	1,700,000	620,000
Douglas Fir	No. 2	900	575	180	625	1350	1,600,000	580,000
Western Larch	No. 3	525	325	180	625	775	1,400,000	510,000
	Construction	1000	650	180	625	1650	1,500,000	550,000
	Standard	575	375	180	625	1400	1,400,000	510,000
	Utility	275	175	180	625	900	1,300,000	470,000
	Stud	700	450	180	625	850	1,400,000	510,000
Douglas Fir-South	Select Structural	1350	900	180	520	1600	1,400,000	510,000
	No. 1	925	600	180	520	1450	1,300,000	470,000
	No. 2	850	525	180	520	1350	1,200,000	440,000
Douglas Fir-South	No. 3	500	300	180	520	775	1,100,000	400,000
(grown in AZ, CO, NV, NM and UT)	Construction	975	600	180	520	1650	1,200,000	440,000
	Standard	550	350	180	520	1400	1,100,000	400,000
	Utility	250	150	180	520	900	1,000,000	370,000
	Stud	675	425	180	520	850	1,100,000	400,000
Hem-Fir	Select Structural	1400	925	150	405	1500	1,600,000	580,000
	No. 1 & Btr.	1100	725	150	405	1350	1,500,000	550,000
Western Hemlock	No. 1	975	625	150	405	1350	1,500,000	550,000
Noble Fir	No. 2	850	525	150	405	1300	1,300,000	470,000
California Red Fir	No. 3	500	300	150	405	725	1,200,000	440,000
Grand Fir	Construction	975	600	150	405	1550	1,300,000	470,000
Pacific Silver Fir	Standard	550	325	150	405	1300	1,200,000	440,000
White Fir	Utility	250	150	150	405	850	1,100,000	400,000
	Stud	675	400	150	405	800	1,200,000	440,000
Spruce-Pine-Fir (South)	Select Structural	1300	575	135	335	1200	1,300,000	470,000
	No. 1	875	400	135	335	1050	1,200,000	440,000
	No. 2	775	350	135	335	1000	1,100,000	400,000
Western Species:	No. 3	450	200	135	335	575	1,000,000	370,000
Engelmann Spruce	Construction	875	400	135	335	1200	1,000,000	370,000
Sitka Spruce	Standard	500	225	135	335	1000	900,000	330,000
White Spruce	Utility	225	100	135	335	675	900,000	330,000
Lodgepole Pine	Stud	600	275	135	335	625	1,000,000	370,000
Western Cedars	Select Structural	1000	600	155	425	1000	1,100,000	400,000
	No. 1	725	425	155	425	825	1,000,000	370,000
Western Red Cedar	No. 2	700	425	155	425	650	1,000,000	370,000
Incense Cedar	No. 3	400	250	155	425	375	900,000	330,000
Port Orford Cedar	Construction	800	475	155	425	850	900,000	330,000
Alaskan Cedar	Standard	450	275	155	425	650	800,000	290,000
	Utility	225	125	155	425	425	800,000	290,000
	Stud	550	325	155	425	400	900,000	330,000
Western Woods (and White Woods[4])	Select Structural	900	400	135	335	1050	1,200,000	440,000
	No. 1	675	300	135	335	950	1,100,000	400,000
Any of the species in the first four species groups above plus any or all of the following:	No. 2	675	300	135	335	900	1,000,000	370,000
Idaho White Pine	No. 3	375	175	135	335	525	900,000	330,000
Ponderosa Pine	Construction	775	350	135	335	1100	1,000,000	370,000
Sugar Pine	Standard	425	200	135	335	925	900,000	330,000
Alpine Fir	Utility	200	100	135	335	600	800,000	290,000
Mountain Hemlock	Stud	525	225	135	335	575	900,000	330,000

[1] Design values in pounds per square inch.

[2] Standard surfaced sizes are tabulated in Table 13.

[3] All horizontal shear values are assigned in accordance with ASTM standards, which include a reduction to compensate for any degree of shake, check or split that might develop in a piece.

[4] White Woods species group includes any species or combination of true firs, spruces, hemlocks or pines. Design values are the same as those assigned to Western Woods.

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4.1.0 Western Lumber Species—Base Values (Continued)

Framing Lumber



ADJUSTMENT FACTORS FOR BASE VALUES

SIZE FACTORS (C_F) Table **A**

Apply to Dimension lumber BASE VALUES

Grades	Nominal Width (depth)	F_b 2" & 3" thick nominal	F_b 4" thick nominal	F_t	F_c	Other Properties
SELECT STRUCTURAL, NO.1 & BTR., NO.1, NO.2 & NO.3	2", 3", & 4"	1.5	1.5	1.5	1.15	1.0
	5"	1.4	1.4	1.4	1.1	1.0
	6"	1.3	1.3	1.3	1.1	1.0
	8"	1.2	1.3	1.2	1.05	1.0
	10"	1.1	1.2	1.1	1.0	1.0
	12"	1.0	1.1	1.0	1.0	1.0
	14" & wider	0.9	1.0	0.9	0.9	1.0
CONSTRUCTION & STANDARD	2", 3", & 4"	1.0	1.0	1.0	1.0	1.0
UTILITY	2" & 3"	0.4	—	0.4	0.6	1.0
	4"	1.0	1.0	1.0	1.0	1.0
STUD	2", 3", & 4"	1.1	1.1	1.1	1.05	1.0
	5" & 6"	1.0	1.0	1.0	1.0	1.0
	8" & wider	Use No.3 grade Base Values and Size Factors				

REPETITIVE MEMBER FACTOR (C_r) Table **B**

Apply to size-adjusted F_b

Where lumber is used repetitively, such as for joists, studs, rafters, and decking, the pieces side by side share the load and the strength of the entire assembly is enhanced. Therefore, where three or more members are adjacent or are not more than 24" on center and are joined by floor, roof, or other load distributing elements, the F_b value can be increased 1.15 for repetitive member use.	Repetitive Member Use
	$F_b \times 1.15$

DURATION OF LOAD ADJUSTMENT (C_D) Table **C**

Apply to size-adjusted values

Wood has the property of carrying substantially greater maximum loads for short durations than for long durations of loading. Tabulated design values apply to normal load duration. (Factors do not apply to MOE or $F_{c\perp}$)

Load Duration	Factor
Permanent	0.9
Ten Years (Normal Load)	1.0
Two Months (Snow Load)	1.15
Seven Day	1.25
Ten Minutes (Wind and Earthquake Loads)	1.6
Impact	2.0

Confirm load requirements with local codes.

HORIZONTAL SHEAR DESIGN VALUES

Horizontal shear values published in Tables 1, 3, 4 and 5 are based upon the maximum degree of shake, check or split that might develop in a piece. Shear design values for lumber have been approved by the American Lumber Standard Committee, Inc.

Design provisions, including requirements for shear design of lumber, are published by the American Forest & Paper Association (AF&PA) in the *National Design Specification for Wood Construction®* *(NDS®)*, an ANSI national consensus standard.

DIMENSION LUMBER

Sizes/Design Values - Dimension lumber includes products that are nominal 2" to 4" in thickness by 2" and wider. It is available in the grades listed in Table 1 (page 6) with assigned design values published as BASE VALUES.

Dimension lumber BASE VALUES must be adjusted for size as well as conditions of use. Adjust the BASE VALUE (Table 1, page 6) according to the size factor (Table A, page 7) before adjusting for conditions of use.

Single member, size-adjusted fiber stress in bending (F_b) design value is for use where the strength of an individual piece, such as a small beam or post, is or may be responsible for carrying a specific design load. Repetitive member use is handled through an adjustment factor (Table B, page 7).

ADJUSTMENTS FOR DIMENSION LUMBER Checklist **1**

The boxes in the checklist below indicate when and how to apply adjustments (Tables A–G) to the BASE VALUES in Table 1.

Base Values x *Adjustment Factors* x *Special Use Factors* = *Design Values*

Base Value	x	Size C_F	x	Repetitive Member C_r	x	Duration of Load C_D	x	Flat Use C_{fu}	x	Compression Perpendicular to Grain $C_{c\perp}$	x	Incising, Wet Use, Fire-Retardant[1], High-Temperature C_i C_M C_R C_t	=	Design Value
F_b		☐		☐		☐		☐				☐		F'_b Bending
F_t		☐				☐						☐		F'_t Tension
F_v						☐						☐		F'_v Shear
$F_{c\perp}$										☐		☐		$F'_{c\perp}$ Compression Perpendicular to Grain
F_c		☐				☐						☐		F'_c Compression Parallel to Grain
E, E_{min}												☐		E', E'_{min} Modulus of Elasticity
Table 1 page 6		Table A		Table B page 7		Table C		Table D page 9		Table E		Ch. 2 of NDS *National Design Specification for Wood Construction*		

[1] Adjustments for fire-retardant treatment shall be provided by the manufacturer providing the treatment.

4.1.0 Western Lumber Species—Base Values (Continued)

Framing Lumber



ADDITIONAL ADJUSTMENT FACTORS FOR DIMENSION LUMBER

FLAT USE FACTORS (C_{fu}) Table **D**

Apply to size-adjusted F_b

Nominal Width	Nominal Thickness 2" & 3"	4"
2" & 3"	1.00	—
4"	1.10	1.00
5"	1.10	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.20	1.10

ADJUSTMENTS FOR COMPRESSION PERPENDICULAR TO GRAIN ($C_{c\perp}$) Table **E**

For deformation basis of 0.02". Apply to $F_{c\perp}$ values

Design values for compression perpendicular to grain ($F_{c\perp}$) are established in accordance with the procedures set forth in ASTM Standards D 2555 and D 245. ASTM procedures consider deformation under bearing loads as a serviceability limit state comparable to bending deflection because bearing loads rarely cause structural failures. Therefore, ASTM procedures for determining compression perpendicular to grain values are based on a deformation basis of 0.04" and are considered adequate for most classes of structures. Where more stringent measures need to be taken in design, the following formula permits the designer to adjust design values to a more conservative deformation basis of 0.02": $F_{c\perp 0.02} = 0.73\ F_{\perp}$

Example: Douglas Fir-Larch: $F_{\perp} = 625$ psi
$F_{c\perp 0.02} = 0.73\ (625) = 456$ psi

WET USE FACTORS (C_M) Table **F**

Apply to size-adjusted values

The design values shown in Tables 1, 2 and 3 are for routine construction applications where the moisture content of the wood does not exceed 19% in use. When use conditions are such that the moisture content of Dimension lumber will exceed 19% in use, the Wet Use Adjustment Factors below are recommended.

Property	Adjustment Factor
F_b	0.85[1]
F_t	1.0
F_c	0.8[2]
F_v	0.97
$F_{c\perp}$	0.67
E, E_{min}	0.9

[1] Wet Use Factor 1.0 for size-adjusted F_b not exceeding 1150 psi.
[2] Wet Use Factor 1.0 for size-adjusted F_c not exceeding 750 psi.

INCISING FACTORS (C_i) Table **G**

Apply to size-adjusted values

Tabulated design values shall be multiplied by the following incising factor (C_i), when Dimension lumber is incised parallel to grain to a maximum depth of 0.4", a maximum length of ⅜", and density of incisions of 1,000/ft². Incising factors shall be determined by test or by calculation using reduced section properties for incising patterns exceeding these limits.

Property	Adjustment Factor
E, E_{min}	0.95
F_b, F_t, F_c, F_v	0.80
$F_{c\perp}$	1.00

SPECIAL DIMENSION LUMBER

There are two categories of Special Dimension lumber grades. Design values are shown in Tables 2 and 3 for these categories:

a. Structural Decking - 2x4 through 4x12;
b. Machine Stress-Rated lumber (MSR) - nominal 2" and less in thickness, 2" and wider.

STRUCTURAL DECKING

Grades/End Uses - Standard decking patterns, in nominal 2" single T&G and 3" and 4" double T&G, are available in vee or eased joints to meet most architectural design requirements. For diagrams of available patterns and sizes, order WWPA's publication *Standard Patterns* (G-16). Two grades are available. **Published design values need to be adjusted for depth effect.** Refer to Tables 2 and H below. Decking spans are provided in Table 10, page 15.

STRUCTURAL DECKING DESIGN VALUES[1] Table **2**

Sizes: 2" to 4" thick, 4" to 12" wide
Use with appropriate Adjustments in Tables C, F, G, H
For flatwise use only

Species	Decking Grade	DRY or MC15 F_b Single Member	F_b Repetitive Member	Compression Perpendicular $F_{c\perp}$	Modulus of Elasticity E	E_{min}
Douglas Fir-Larch	Selected	1750	2000	625	1,800,000	660,000
	Commercial	1450	1650	625	1,700,000	620,000
Douglas Fir-South	Selected	1650	1900	520	1,400,000	510,000
	Commercial	1400	1600	520	1,300,000	470,000
Hem-Fir	Selected	1400	1600	405	1,500,000	550,000
	Commercial	1150	1350	405	1,400,000	510,000
SPFS	Selected	1150	1350	335	1,400,000	510,000
	Commercial	950	1100	335	1,200,000	440,000
Western Cedars	Selected	1250	1450	425	1,100,000	400,000
	Commercial	1050	1200	425	1,000,000	370,000
Western Woods	Selected	1150	1300	335	1,200,000	440,000
	Commercial	950	1100	335	1,100,000	400,000

[1] Design values in pounds per square inch. See Table 1 (page 6) for horizontal shear (F_v) values.

ADJUSTMENT FACTORS FOR DEPTH EFFECT (C_F) Table **H**

For all widths of Structural Decking

Decking bending design values may be adjusted for thickness as shown below because the bending values shown in Table 2 are based on a 4" thick member loaded flatwise.

Nominal Thickness 2"	3"	4"
1.10	1.04	1.00

ADJUSTMENTS FOR STRUCTURAL DECKING Checklist **3**

- ☐ Duration of Load (C_D) — Table C, page 7
- ☐ Wet Use Factor (C_M) — Table F, page 9
- ☐ Incising Factor (C_i) — Table G, page 9
- ☐ Depth Effect (C_F) — Table H, page 9

4.1.1 Western Wood Products Association (WWPA) Grade Markings

Framing Lumber

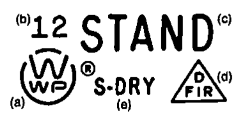
WWPA GRADE STAMPS

Grading practices of WWPA mills are closely supervised by the Association's field team of Lumber Inspectors to assure uniformity and conformance to the *Western Lumber Grading Rules*. These rules establish standards for size and levels of quality in conformance with the American Softwood Lumber Standard PS 20, which can be viewed online at: **http://ts.nist.gov/docvps**

The *Grading Rules* provide the specifier with a dependable measure for determining the quality of lumber. Western lumber grades may be assigned visually or mechanically.

The building codes require that grade-marked lumber be used for structural applications. If practical, appearance grades such as Selects and Commons used for siding, paneling and soffits, may be specified end stamped. Most grade stamps, except those for rough lumber or heavy timbers, contain the five basic elements shown below:

a. WWPA Certification Mark: Certifies Association quality supervision. ® is a registered trademark.



b. Mill Identification: Firm name, brand or assigned mill number. A WWPA mill number list is available online at **www.wwpa.org/millno.htm**.

c. Grade Designation: Grade name, number or abbreviation.

d. Species Identification: Indicates species by individual species or species combination. Other species identification marks are shown in the species list on page 4.

e. Condition of Seasoning: Indicates condition of seasoning at the time of surfacing–

S-GRN	- over 19% moisture content (unseasoned)
S-DRY, KD or KD HT	- 19% maximum moisture content
MC15 or KD15	- 15% maximum moisture content

KD HT LUMBER GRADE STAMP

A KD HT mark, indicating the wood has been kiln dried (KD) and heat-treated (HT), is used to meet international regulations for wood pallet and packaging materials. The mark indicates lumber has been dried to a maximum moisture content of 19 percent or less, and was heat-treated to a lumber core temperature of 56°C for a minimum of 30 minutes.

For structural framing applications, including Metal Plate Connected (MPC) wood trusses, the KD HT mark can be considered the same as surfaced dry (S-DRY) and KD.

LUMBER DESIGN VALUES

Design values for North American softwood structural lumber are determined in accordance with ASTM standards based on clear-wood tests and tests of graded lumber pieces. The applicable standards, based on results of tests conducted in cooperation with the USDA Forest Products Laboratory, are *ASTM Standards D 2555* and *D 245* for clear-wood, and *D 1990* for graded lumber specimens. Refer to Sections 100.00 to 180.00 of the *Western Lumber Grading Rules* for additional information.

Design values are published in the *Western Lumber Grading Rules*, incorporated into the *Supplement* to the *National Design Specification for Wood Construction® (NDS®)*, and are shown on the following pages of this publication; for NGR Dimension lumber in Table 1 (page 6) and for Timbers in Tables 4 and 5 (page 11). These design values are recognized by the model building codes. For any alternate species combinations (other than the standard species combinations) the species of lowest assigned design value governs the combination.

FRAMING LUMBER

The general classifications of framing lumber are Dimension, Special Dimension and Timbers. The lumber grades within these classifications are intended for structural applications in load-bearing situations.

The design values for Dimension lumber in Table 1 are published as BASE VALUES. BASE VALUES are constants that are applied to each grade in a particular species grouping. BASE VALUES *must be adjusted for size*, using the SIZE-ADJUSTMENT FACTORS in Table A. Design values in Table 3 are published in a SIZE-ADJUSTED FORMAT, and no size adjustment is necessary. All design values (in Tables 1-5) must be adjusted for conditions of use (Tables B-K) as appropriate. Refer to pages 7-9 for more information on using BASE VALUES. The checklists, after each classification of lumber, serve as reminders as to when and how to apply adjustments to the numbers in each table of design values.

Mechanical Properties - Lumber strength properties are assigned to five basic properties: fiber stress in bending (F_b), tension parallel to grain (F_t), horizontal shear (F_v), compression perpendicular to grain ($F_{c\perp}$) and compression parallel to grain (F_c). The modulus of elasticity (*E* or *MOE*) is a ratio of the amount a piece of lumber will deflect in proportion to an applied load. It is a measurement of stiffness and not a strength property. E_{min} is the modulus of elasticity for beam and column stability calculations. Refer to pages 12 and 13 for a description of these properties.

Western lumber design values are for use in all normal construction design. Higher or lower design values may be used to meet special structural requirements. Standard ASTM reductions have been made to the strength values to account for safety and duration of load. The *National Design Specification for Wood Construction® (NDS®)*, published by the American Forest & Paper Association, **www.awc.org**, 1111 19th Street, NW, Eighth Floor, Washington, DC 20036, sets forth design methods for structural applications.

Moisture Content and Heat Treating - Any of the abbreviations, S-GRN, HT, S-DRY, KD, KD HT, MC15, or KD15 may be found in a grade stamp to denote the moisture content (MC) of lumber at the time of surfacing. Designations are explained in the left column.

Unseasoned (S-GRN) lumber is manufactured oversized so that when it reaches 19% MC it will be approximately the same size as the dry size. Therefore, when unseasoned lumber is shipped, the same design values that are assigned and used for dry lumber also apply to S-GRN lumber.

Heat Treated (HT) lumber is lumber that has been placed in a closed chamber and heat added until the lumber achieves a minimum core temperature of 56°C for a minimum of 30 minutes.

The word "DRY" indicates that a product was either kiln or air dried to a maximum moisture content of 19%. Kiln-dried (KD) lumber is lumber that has been seasoned in a chamber to a pre-determined moisture content by applying heat.

Kiln Dried Heat Treated (KD HT) lumber is lumber that has been placed in a closed chamber and heat added until the lumber achieves a minimum core temperature of 56°C for a minimum of 30 minutes and which is dried to a maximum moisture content of 19% or less.

Framing lumber 2" and less in thickness may be seasoned to a moisture content of 19% or less, with the indication "S-DRY" or "KD" on the grade stamp. Surfaced framing lumber over 2" in thickness is typically shipped unseasoned and indicated "S-GRN" on the grade stamp. Regional market conditions dictate the availability of dry or unseasoned material.

4.1.2 Western Lumber Species Marketing Categories

Western Lumber Species and Grades

WESTERN LUMBER SPECIES MARKETING CATEGORIES

Standard Species Combinations		Western Softwood Species	
WEST WOODS — Western Woods	DOUG FIR-L — Douglas Fir-Larch	D FIR	Douglas Fir— *Pseudotsuga menziesii*
		WL	Western Larch—*Larix occidentalis*
	D FIR S — Douglas Fir-South	D FIR S	Douglas Fir-South— *Pseudotsuga menziesii* (Grown in AZ, CO, NV, NM and UT)
	HEM FIR — Hem-Fir	HEM	Western Hemlock—*Tsuga heterophylla*
			Noble Fir—*Abies procera*
			California Red Fir—*Abies magnifica*
			Grand Fir—*Abies grandis*
			Pacific Silver Fir—*Abies amabilis*
			White Fir—*Abies concolor*
	SPFs — Spruce-Pine-Fir (South)	SS	Sitka Spruce—*Picea sitchensis*
		ES	Engelmann Spruce—*Picea engelmannii*
		LP	Lodgepole Pine—*Pinus contorta*
		ALPINE FIR	Alpine Fir—*Abies lasiocarpa* (or Subalpine Fir)
		PP	Ponderosa Pine—*Pinus ponderosa*
		SP	Sugar Pine—*Pinus lambertiana*
		IWP	Idaho White Pine—*Pinus monticola* (or Western White Pine)
		M HEM	Mountain Hemlock—*Tsuga mertensiana*
	WEST CDR — Western Cedars	INC CDR	Incense Cedar—*Libocedrus decurrens*
		WR CDR	Western Red Cedar—*Thuja plicata*
			Port Orford Cedar—*Chamaecyparis lawsoniana*
			Alaskan Cedar—*Chamaecyparis nootkatensis*

WW — White Woods *(any combination of the Western true firs, spruces, hemlocks or pines)*

Alternate Species Combinations

Mark	Species
WHITE FIR	Noble Fir, California Red Fir, Grand Fir, Pacific Silver Fir, White Fir
ES LP	Engelmann Spruce-Lodgepole Pine
A-F HEM FIR	Alpine Fir-Hem-Fir
PPSP	Ponderosa Pine-Sugar Pine
ES·AF	Engelmann Spruce-Alpine Fir
ES LP AF	Engelmann Spruce-Lodgepole Pine-Alpine Fir
PP-LP	Ponderosa Pine-Lodgepole Pine

GRADE CATEGORIES

Western solid-sawn lumber is grouped into three broad categories: framing (or structural) lumber, which is graded for strength; appearance lumber, which is not graded for strength; and industrial (or factory) lumber, which is generally graded for specific end uses or for remanufacturing and recovery purposes.

Framing lumber includes the grades intended for structural applications in both conventional and pre-engineered framing systems. Western species structural lumber is manufactured primarily from second- and third-growth softwoods and graded, either visually or mechanically, on the basis of its strength; each species and grade has an assigned design value. General classifications include:

- Dimension lumber grades
- Special Dimension lumber grades
- Timber grades

Design values for Dimension lumber are published as BASE VALUES which must be adjusted for size as well as conditions of use. Refer to pages 5 to 17.

Appearance lumber includes a variety of non-structural grades intended for applications where strength is not the primary consideration. Appearance grade Western lumber is manufactured primarily from older (not "old growth") and second-growth softwood trees. Many of the products in this category are often run-to-pattern for paneling and siding applications. General classifications include:

- High-quality Appearance grades
  (Selects, Finish and Special Western Red Cedar Grades)
- General purpose Board grades
  (Commons under WWPA Rules and
  Alternate Board Grades under WCLIB Rules)
- Radius-edged Patio Decking grades
  (Patio 1 and Patio 2)

Refer to pages 18 to 20.

Industrial lumber includes both structural and non-structural grades intended for specific applications. General classifications include:

- Structural grades
  (Mining Timbers, Scaffold Plank, Foundation lumber, Stress-Rated Boards)
- Factory and Shop grades
  (non-structural grades intended for cut up and remanufacturing)
- Non-structural grades
  (Gutter, Picket, Lath, Batten, Stepping)

Refer to pages 21 and 22.

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4.1.3 Machine Stress-Rated (MSR) Lumber

Framing Lumber

MSR LUMBER

Machine Stress-Rated lumber (MSR) is Dimension lumber that has been evaluated by mechanical stress-rating equipment. The stress-rating equipment measures the stiffness of the material and sorts it into various modulus of elasticity (*E*) classes.

Research has shown that a direct relationship exists between the bending stiffness of a piece of lumber, its bending strength or modulus of rupture (MOR), and its ultimate tensile strength (UTS).

Since the only way to determine strength values is to actually break the piece, the next best alternative is to measure the stiffness, compute the modulus of elasticity, and then predict the strength values.

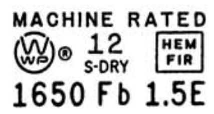
Following this "*E*" sorting, each piece must also meet certain visual requirements and daily quality control test procedures for both F_b and *E*.

Voluntary procedures - Because there is a direct relationship between specific gravity values and MSR lumber grades (with higher-strength grades having higher specific gravity values), some MSR lumber producers provide voluntary daily quality control for specific gravity (*SG*) and/or tension (F_t) in addition to the mandatory F_b and *E* testing. When these additional levels of quality control are provided, the producer may include the appropriate F_t, *SG* and specific gravity-related compression perpendicular to grain value ($F_{C\perp}$), and horizontal shear (F_V) values on the grade stamp in addition to F_b and *E*. MSR producers providing one or more of these additional levels of quality control may choose to limit the number of grades which are subject to F_t and *SG* testing.

End Uses - One of the prime uses for Machine Stress-Rated lumber is trusses. However, this product is also used as floor and ceiling joists, as rafters and for other structural purposes where assured strength capabilities are primary product considerations.

Code Acceptability - MSR lumber produced under an approved grading agency's certification and quality control procedures is accepted by regulatory agencies and all major building codes.

Refer to page 17 for information on specifying MSR lumber. Order WWPA's *Machine Stress-Rated Lumber* (TG-4) publication for additional information on MSR products and quality control procedures.



Typical MSR Stamp

12 MSR S-DRY SPF[S]
WWP ® 2400Fb 1925Ft
2.0E .50SG

MSR Stamp with Tension and Specific Gravity Quality Control

When MSR lumber is visually graded for optional wane limitations as described in WWPA's ***Western Lumber Grade Rules***, the grade stamp includes the mark "1W".

DESIGN VALUES

When designing with MSR lumber, the appropriate adjustments in Tables B-G must be applied to the numbers in Table 3.

F_b: For any given value of F_b the average modulus of elasticity (*E*), may vary depending on species, timber source and other variables. The *E* value included in the F_b-*E* grade designations in Table 3 are those usually associated with each F_b level. Grade stamps may show higher or lower *E* values (in increments of 100,000 psi) if machine rating indicates the assignment is appropriate. When an *E* value varies from the designated F_b level in the table, the tabulated F_b, F_t and F_c values associated with the designated F_b value are applicable.

DESIGN VALUES[1] Table **3**
MACHINE STRESS-RATED LUMBER
2" and less in thickness, 2" and wider
Use with appropriate Adjustments in Tables B through G

Grade Designation	F_b Single	E	E_{min}	F_t	F_c
2850 F_b-2.3E	2850	2,300,000	1,170,000	2300	2150
2700 F_b-2.2E	2700	2,200,000	1,120,000	2150	2100
2550 F_b-2.1E	2550	2,100,000	1,070,000	2050	2025
2400 F_b-2.0E	2400	2,000,000	1,020,000	1925	1975
2250 F_b-1.9E	2250	1,900,000	970,000	1750	1925
2100 F_b-1.8E	2100	1,800,000	910,000	1575	1875
1950 F_b-1.7E	1950	1,700,000	860,000	1375	1800
1800 F_b-1.6E	1800	1,600,000	810,000	1175	1750
1650 F_b-1.5E	1650	1,500,000	760,000	1020	1700
1500 F_b-1.4E	1500	1,400,000	710,000	900	1650
1450 F_b-1.3E	1450	1,300,000	660,000	800	1625
1350 F_b-1.3E	1350	1,300,000	660,000	750	1600
1200 F_b-1.2E	1200	1,200,000	610,000	600	1400
900 F_b-1.0E	900	1,000,000	510,000	350	1050

[1] Design values in pounds per square inch

$F_{C\perp}$ and F_V: Design values for compression perpendicular to grain ($F_{C\perp}$), and horizontal shear (F_V), are the same as assigned to visually graded lumber of the appropriate species. These average $F_{C\perp}$ and F_V values for Western lumber are provided in Table 1, page 6.

DERIVING COMPRESSION PERPENDICULAR TO GRAIN VALUE (Fc>)

When a grade of MSR lumber is qualified by testing and daily quality control for specific gravity (SG), the allowable $F_{C\perp}$ value may be calculated by the following formula:

$$F_{C\perp} = (2252.4 \times SG) - 480$$

$F_{C\perp}$ values, determined by the above equation, are based on a 0.04" deformation limit and are for the design of most structures. Values based on 0.02" deformation can be obtained with the following formulas:

$$F_{C\perp 0.02} = 14.6 + (0.71 \times F_{C\perp})$$

$$F_{C\perp 0.02} = (1605.5 \times SG) - 327.5$$

DERIVING HORIZONTAL SHEAR VALUE (F_V)

When a grade of MSR lumber is qualified by testing and daily quality control for specific gravity (SG), the allowable F_V value may be calculated using the following formula:

$$F_V = 40 + (266 \times SG)$$

4.1.4 Mechanical Properties of Western Lumber (Illustrated)

Framing Lumber

MECHANICAL PROPERTIES ILLUSTRATED

Extreme Fiber Stress in Bending - *F_b* (Fig. 1) When loads are applied, structural members bend, producing tension in the fibers along the faces farthest from the applied load and compression in the fibers along the face nearest to the applied load. These induced stresses in the fibers are designated as "extreme fiber stress in bending" (F_b).

Single Member F_b design values are used in design where the strength of an individual piece, such as a beam, may be solely responsible for carrying a specific design load.

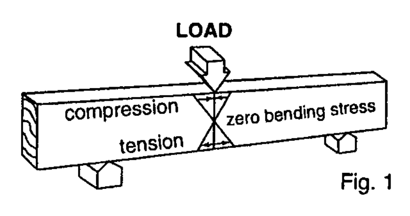
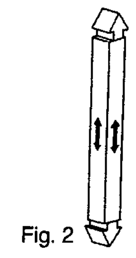


Fig. 1

Repetitive Member F_b design values are used in design when three or more load sharing members, such as joists, rafters, or studs, are spaced no more than 24" apart and are joined by flooring, sheathing or other load-distributing elements. Repetitive members are also used where pieces are adjacent, such as decking.

Fiber Stress in Tension - *F_t* (Fig. 2)
Tensile stresses are similar to compression parallel to grain in that they act across the full cross section and tend to stretch the piece. Length does not affect tensile stresses.


Fig. 2

Horizontal Shear - *F_v*
(Fig. 3) Horizontal shear stresses tend to slide fibers over each other horizontally. Most predominate in short, heavily loaded deep beams. Increasing beam cross section decreases shear stresses.

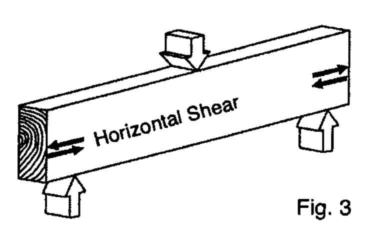


Fig. 3

Compression Perpendicular to Grain - *$F_{c\perp}$* (Fig. 4)
Where a joist, beam or similar piece of lumber bears on supports, the load tends to compress the fibers. It is necessary that the bearing area be sufficient to prevent excessive side-grain crushing.

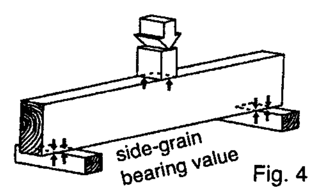
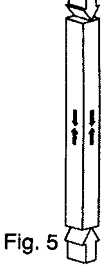


Fig. 4

Compression Parallel to Grain - *F_c* (Fig. 5)
In many parts of a structure, stress grades are used where the loads are supported on the ends of the pieces. Such uses are as studs, posts, columns and struts. The internal stress induced by this kind of loading is the same across the whole cross section and the fibers are uniformly stressed parallel to and along the full length of the piece.


Fig. 5

Modulus of Elasticity - *E* (Fig. 6)
The modulus of elasticity is a ratio of the amount a material will deflect in proportion to an applied load.

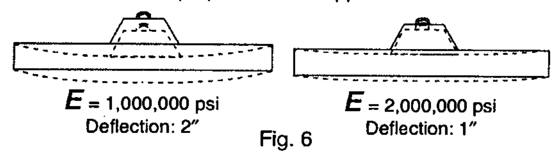


Fig. 6

Note: Modulus of Elasticity - E_{min}
E_{min} is the modulus of elasticity for beam and column stability calculations.

Used courtesy of Western Wood Products Assn.

4.1.5 Standard Sizes of Framing Lumber

STANDARD SIZES - FRAMING LUMBER Table **6**

Nominal & Dressed (Based on *Western Lumber Grading Rules*)

Product	Description	Nominal Size Thickness inch	Nominal Size Width inch	Dressed (surfaced) Size, Thicknesses & Widths: Surfaced Dry inch	Surfaced Dry mm	Surfaced Unseasoned inch	Surfaced Unseasoned mm	Length feet
DIMENSION	S4S	2	2	$1\frac{1}{2}$	38	$1\frac{9}{16}$	40	6′ (183 cm) and longer, generally shipped in multiples of 2′ (61 cm)
		3	3	$2\frac{1}{2}$	64	$2\frac{9}{16}$	65	
		4	4	$3\frac{1}{2}$	89	$3\frac{9}{16}$	90	
			5	$4\frac{1}{2}$	114	$4\frac{5}{8}$	117	
			6	$5\frac{1}{2}$	140	$5\frac{5}{8}$	143	
			8	$7\frac{1}{4}$	184	$7\frac{1}{2}$	191	
			10	$9\frac{1}{4}$	235	$9\frac{1}{2}$	241	
			12	$11\frac{1}{4}$	289	$11\frac{1}{2}$	292	
			over 12	$\frac{3}{4}$ off nominal	19 off nominal	$\frac{1}{2}$ off nominal	13 off nominal	
				Thickness Unseasoned		**Width Unseasoned**		
TIMBERS	Rough or S4S (shipped unseasoned)	5 and larger	5 and larger	½″ (13mm) off nominal (S4S). See 3.20 of WWPA Grading Rules for Rough.				6′ (183 cm) and longer, generally shipped in multiples of 2′ (61 cm)
		Thickness	**Width**	**Thickness Dry** inch	mm	**Width Dry** inch	mm	
DECKING	2″ (Single T&G)	2	5	$1\frac{1}{2}$	38	4	102	6′ (183 cm) and longer, generally shipped in multiples of 2′ (61 cm)
			6			5	127	
			8			$6\frac{3}{4}$	172	
			10			$8\frac{3}{4}$	222	
			12			$10\frac{3}{4}$	273	
	3″ and 4″ (Double T&G)	3	6	$2\frac{1}{2}$	64	$5\frac{1}{4}$	133	
		4		$3\frac{1}{2}$	89			

Abbreviations: T&G—Tongued and grooved Rough—Unsurfaced S4S—Surfaced four sides

Note on Metrics: Metric equivalents are provided for surfaced (actual) sizes.

Used courtesy of Western Wood Products Assn.

4.1.6 Floor Joist Spans for Western Lumber

Framing Lumber

FLOOR JOIST SPANS[1] Table **7**

40# LIVE LOAD 10# DEAD LOAD
L/360
Design Criteria: *Strength* - 10 lbs. per sq. ft. dead load plus 40 lbs. per sq. ft. live load.
Deflection - Limited in span in inches divided by 360 for live load only.

Species or Group	Grade	2 x 8 12"	2 x 8 16"	2 x 8 19.2"	2 x 8 24"	2 x 10 12"	2 x 10 16"	2 x 10 19.2"	2 x 10 24"	2 x 12 12"	2 x 12 16"	2 x 12 19.2"	2 x 12 24"	2 x 14 12"	2 x 14 16"	2 x 14 19.2"	2 x 14 24"
Douglas Fir-Larch	Sel. Struc.	15-0	13-7	12-10	11-11	19-1	17-4	16-4	15-2	23-3	21-1	19-10	18-5	27-4	24-10	23-5	21-4
	1 & Btr.	14-8	13-4	12-7	11-8	18-9	17-0	16-0	14-9	22-10	20-9	19-1	17-1	26-10	23-4	21-4	19-1
	No. 1	14-5	13-1	12-4	11-0	18-5	16-5	15-0	13-5	22-0	19-1	17-5	15-7	24-7	21-4	19-5	17-5
	No. 2	14-2	12-9	11-8	10-5	18-0	15-7	14-3	12-9	20-11	18-1	16-6	14-9	23-4	20-3	18-5	16-6
	No. 3	11-3	9-9	8-11	8-0	13-9	11-11	10-11	9-9	16-0	13-10	12-7	11-3	17-10	15-5	14-1	12-7
Douglas Fir-South	Sel. Struc.	13-6	12-3	11-7	10-9	17-3	15-8	14-9	13-8	21-0	19-1	17-11	16-8	24-8	22-5	21-1	19-7
	No. 1	13-2	12-0	11-3	10-6	16-10	15-3	14-5	12-11	20-6	18-4	16-9	15-0	23-8	20-6	18-9	16-9
	No. 2	12-10	11-8	11-0	10-2	16-5	14-11	13-10	12-5	19-11	17-7	16-1	14-4	22-8	19-8	17-11	16-1
	No. 3	11-0	9-6	8-8	7-9	13-5	11-8	10-7	9-6	15-7	13-6	12-4	11-0	17-5	15-1	13-9	12-4
Hem-Fir	Sel. Struc.	14-2	12-10	12-1	11-3	18-0	16-5	15-5	14-4	21-11	19-11	18-9	17-5	25-10	23-6	22-1	20-6
	1 & Btr.	13-10	12-7	11-10	11-0	17-8	16-0	15-1	14-0	21-6	19-6	18-3	16-4	25-3	22-4	20-5	18-3
	No. 1	13-10	12-7	11-10	10-10	17-8	16-0	14-10	13-3	21-6	18-10	17-2	15-5	24-4	21-1	19-3	17-2
	No. 2	13-2	12-0	11-3	10-2	16-10	15-2	13-10	12-5	20-4	17-7	16-1	14-4	22-8	19-8	17-11	16-1
	No. 3	11-0	9-6	8-8	7-9	13-5	11-8	10-7	9-6	15-7	13-6	12-4	11-0	17-5	15-1	13-9	12-4
Spruce-Pine-Fir (South)	Sel. Struc.	13-2	12-0	11-3	10-6	16-10	15-3	14-5	13-4	20-6	18-7	17-6	16-3	24-1	21-11	20-7	19-2
	No. 1	12-10	11-8	11-0	10-2	16-5	14-11	14-0	12-7	19-11	17-10	16-3	14-7	23-0	19-11	18-2	16-3
	No. 2	12-6	11-4	10-8	9-8	15-11	14-6	13-3	11-10	19-4	16-10	15-4	13-9	21-8	18-9	17-2	15-4
	No. 3	10-5	9-0	8-3	7-5	12-9	11-0	10-1	9-0	14-9	12-10	11-8	10-5	16-6	14-4	13-1	11-8
Western Woods	Sel. Struc.	12-10	11-8	11-0	10-2	16-5	14-11	14-0	12-9	19-11	18-1	16-6	14-9	23-4	20-3	18-5	16-6
	No. 1	12-6	11-1	10-1	9-0	15-7	13-6	12-4	11-0	18-1	15-8	14-4	12-10	20-3	17-6	16-0	14-4
	No. 2	12-1	11-0	10-1	9-0	15-5	13-6	12-4	11-0	18-1	15-8	14-4	12-10	20-3	17-6	16-0	14-4
	No. 3	9-6	8-3	7-6	6-9	11-8	10-1	9-2	8-3	13-6	11-8	10-8	9-6	15-1	13-1	11-11	10-8

Span (feet and inches); spacing on center.

FLOOR JOIST SPANS[1] Table **8**

30# LIVE LOAD 10# DEAD LOAD
L/360
Design Criteria: *Strength* - 10 lbs. per sq. ft. dead load plus 30 lbs. per sq. ft. live load.
Deflection - Limited in span in inches divided by 360 for live load only.

Species or Group	Grade	2 x 6 12"	2 x 6 16"	2 x 6 19.2"	2 x 6 24"	2 x 8 12"	2 x 8 16"	2 x 8 19.2"	2 x 8 24"	2 x 10 12"	2 x 10 16"	2 x 10 19.2"	2 x 10 24"	2 x 12 12"	2 x 12 16"	2 x 12 19.2"	2 x 12 24"
Douglas Fir-Larch	Sel. Struc.	12-6	11-4	10-8	9-11	16-6	15-0	14-1	13-1	21-0	19-1	18-0	16-8	25-7	23-3	21-10	20-3
	1 & Btr.	12-3	11-2	10-6	9-9	16-2	14-8	13-10	12-10	20-8	18-9	17-8	16-5	25-1	22-10	21-4	19-1
	No. 1	12-0	10-11	10-4	9-7	15-10	14-5	13-7	12-4	20-3	18-5	16-9	15-0	24-8	21-4	19-6	17-5
	No. 2	11-10	10-9	10-1	9-3	15-7	14-2	13-0	11-8	19-10	17-5	15-11	14-3	23-4	20-3	18-6	16-6
	No. 3	9-11	8-7	7-10	7-0	12-7	10-11	10-0	8-11	15-5	13-4	12-2	10-11	17-10	15-5	14-1	12-7
Douglas Fir-South	Sel. Struc.	11-3	10-3	9-8	8-11	14-11	13-6	12-9	11-10	19-0	17-3	16-3	15-1	23-1	21-0	19-9	18-4
	No. 1	11-0	10-0	9-5	8-9	14-6	13-2	12-5	11-6	18-6	16-10	15-10	14-5	22-6	20-6	18-9	16-9
	No. 2	10-9	9-9	9-2	8-6	14-2	12-10	12-1	11-3	18-0	16-5	15-5	13-10	21-11	19-8	17-11	16-1
	No. 3	9-8	8-5	7-8	6-10	12-4	10-8	9-9	8-8	15-0	13-0	11-10	10-7	17-5	15-1	13-9	12-4
Hem-Fir	Sel. Struc.	11-10	10-9	10-1	9-4	15-7	14-2	13-4	12-4	19-10	18-0	17-0	15-9	24-2	21-11	20-8	19-2
	1 & Btr.	11-7	10-6	9-10	9-2	15-3	13-10	13-0	12-1	19-5	17-8	16-7	15-5	23-7	21-6	20-2	18-3
	No. 1	11-7	10-6	9-10	9-2	15-3	13-10	13-0	12-1	19-5	17-8	16-7	14-10	23-7	21-1	19-3	17-2
	No. 2	11-0	10-0	9-5	8-9	14-6	13-2	12-5	11-4	18-6	16-10	15-6	13-10	22-6	19-8	17-11	16-1
	No. 3	9-8	8-5	7-8	6-10	12-4	10-8	9-9	8-8	15-0	13-0	11-10	10-7	17-5	15-1	13-9	12-4
Spruce-Pine-Fir (South)	Sel. Struc.	11-0	10-0	9-5	8-9	14-6	13-2	12-5	11-6	18-6	16-10	15-10	14-8	22-6	20-6	19-3	17-11
	No. 1	10-9	9-9	9-2	8-6	14-2	12-10	12-1	11-3	18-0	16-5	15-5	14-1	21-11	19-11	18-3	16-3
	No. 2	10-5	9-6	8-11	8-3	13-9	12-6	11-9	10-10	17-6	15-11	14-9	13-3	21-4	18-9	17-2	15-4
	No. 3	9-3	8-0	7-3	6-6	11-8	10-1	9-3	8-3	14-3	12-4	11-3	10-1	16-6	14-4	13-1	11-8
Western Woods	Sel. Struc.	10-9	9-9	9-2	8-6	14-2	12-10	12-1	11-3	18-0	16-5	15-5	14-3	21-11	19-11	18-6	16-6
	No. 1	10-5	9-6	8-11	8-0	13-9	12-4	11-4	10-1	17-5	15-1	13-10	12-4	20-3	17-6	16-0	14-4
	No. 2	10-1	9-2	8-8	8-0	13-4	12-1	11-4	10-1	17-0	15-1	13-10	12-4	20-3	17-6	16-0	14-4
	No. 3	8-5	7-3	6-8	5-11	10-8	9-3	8-5	7-6	13-0	11-3	10-3	9-2	15-1	13-1	11-11	10-8

Span (feet and inches); spacing on center.

[1] *Spans for other loads are provided in WWPA's* ***Western Lumber Span Tables*** *(572). Spans for other grades and Western Cedars may be calculated with any of WWPA's design aids: the WWPA* ***Span Computer*** *(SR), a slide rule-style calculator;* ***DesignEasy****, a spreadsheet program for PDA devices; or the* ***Lumber Design Suite****, a spreadsheet program.*

Used courtesy of Western Wood Products Assn.

4.1.7 Ceiling Joist, Structural Decking Spans for Western Lumber

Framing Lumber

CEILING JOIST SPANS Table **9**

20# LIVE LOAD 10# DEAD LOAD

L/240

Design Criteria: *Strength* - 10 lbs. per sq. ft. dead load plus 20 lbs. per sq. ft. live load.
Deflection - Limited in span in inches divided by 240 for live load only.

Species or Group	Grade	Span (feet and inches)															
		2 x 6				2 x 8				2 x 10				2 x 12			
		spacing on center															
		12"	16"	19.2"	24"	12"	16"	19.2"	24"	12"	16"	19.2"	24"	12"	16"	19.2"	24"
Douglas Fir-Larch	Sel. Struc.	16-4	14-11	14-0	13-0	21-7	19-7	18-5	17-2	27-6	25-0	23-7	21-3	33-6	30-2	27-6	24-8
	1 & Btr.	16-1	14-7	13-9	12-3	21-2	19-1	17-5	15-7	26-10	23-3	21-3	19-0	31-2	27-0	24-8	22-0
	No. 1	15-9	13-9	12-6	11-2	20-1	17-5	15-10	14-2	24-6	21-3	19-5	17-4	28-5	24-8	22-6	20-1
	No. 2	15-0	13-0	11-11	10-8	19-1	16-6	15-1	13-6	23-3	20-2	18-5	16-5	27-0	23-4	21-4	19-1
	No. 3	11-6	9-11	9-1	8-1	14-7	12-7	11-6	10-3	17-9	15-5	14-1	12-7	20-7	17-10	16-3	14-7
Douglas Fir-South	Sel. Struc.	14-9	13-5	12-8	11-9	19-6	17-9	16-8	15-6	24-10	22-7	21-3	19-9	30-3	27-6	25-10	23-4
	No. 1	14-5	13-1	12-1	10-9	19-0	16-9	15-3	13-8	23-7	20-5	18-8	16-8	27-4	23-8	21-7	19-4
	No. 2	14-1	12-8	11-7	10-4	18-6	16-0	14-8	13-1	22-7	19-7	17-10	16-0	26-3	22-8	20-9	18-6
	No. 3	11-2	9-8	8-10	7-11	14-2	12-4	11-3	10-0	17-4	15-0	13-8	12-3	20-1	17-5	15-11	14-3
Hem-Fir	Sel. Struc.	15-6	14-1	13-3	12-3	20-5	18-6	17-5	16-2	26-0	23-8	22-3	20-6	31-8	28-9	26-7	23-9
	1 & Btr.	15-2	13-9	12-11	11-9	19-11	18-2	16-8	14-11	25-5	22-3	20-4	18-2	29-10	25-10	23-7	21-1
	No. 1	15-2	13-7	12-4	11-1	19-10	17-2	15-8	14-0	24-3	21-0	19-2	17-1	28-1	24-4	22-2	19-10
	No. 2	14-5	12-8	11-7	10-4	18-6	16-0	14-8	13-1	22-7	19-7	17-10	16-0	26-3	22-8	20-9	18-6
	No. 3	11-2	9-8	8-10	7-11	14-2	12-4	11-3	10-0	17-4	15-0	13-8	12-3	20-1	17-5	15-11	14-3
Spruce-Pine-Fir (South)	Sel. Struc.	14-5	13-1	12-4	11-5	19-0	17-3	16-3	15-1	24-3	22-1	20-9	19-3	29-6	26-10	25-3	22-11
	No. 1	14-1	12-9	11-9	10-6	18-6	16-3	14-10	13-3	22-11	19-10	18-2	16-3	26-7	23-0	21-0	18-10
	No. 2	13-8	12-1	11-0	9-10	17-8	15-4	14-0	12-6	21-7	18-8	17-1	15-3	25-0	21-8	19-9	17-8
	No. 3	10-8	9-3	8-5	7-6	13-6	11-8	10-8	9-6	16-5	14-3	13-0	11-8	19-1	16-6	15-1	13-6
Western Woods	Sel. Struc.	14-1	12-9	11-11	10-8	18-6	16-6	15-1	13-6	23-3	20-2	18-5	16-5	27-0	23-4	21-4	19-1
	No. 1	13-0	11-3	10-4	9-3	16-6	14-3	13-0	11-8	20-2	17-5	15-11	14-3	23-4	20-3	18-6	16-6
	No. 2	13-0	11-3	10-4	9-3	16-6	14-3	13-0	11-8	20-2	17-5	15-11	14-3	23-4	20-3	18-6	16-6
	No. 3	9-8	8-5	7-8	6-10	12-4	10-8	9-9	8-8	15-0	13-0	11-10	10-7	17-5	15-1	13-9	12-4

STRUCTURAL DECKING SPANS Table **10**

Spans for 4" to 12" wide lumber manufactured and used at a maximum moisture content of 19%.
Spans are given in feet-inches.

Species / Grade	2" Thick Decking												3" Thick Decking											
	Douglas Fir-Larch		Douglas Fir-South		Hem-Fir		Spruce-Pine-Fir (South)		Western Cedars		Western Woods		Douglas Fir-Larch		Douglas Fir-South		Hem-Fir		Spruce-Pine-Fir (South)		Western Cedars		Western Woods	
	Sel.	Com.	Sel.	Com.	Sel.	Com.	Sel.	Com.	Sel.	Com.	Sel.	Com.	Sel.	Com.	Sel	Com.	Sel.	Com.	Sel.	Com.	Sel.	Com.	Sel.	Com.
FLOOR DECKING - 10 psf Dead Load / 40 psf Live Load (normal load) — L/480 Deflection Limit																								
Simple	5-6	5-5	5-1	4-11	5-2	5-1	5-1	4-10	4-8	4-7	4-10	4-8	9-3	9-0	8-6	8-3	8-8	8-6	8-6	8-1	7-10	7-7	8-1	7-10
Controlled Random	6-0	5-11	5-7	5-5	5-8	5-7	5-7	5-3	5-1	5-0	5-3	5-1	10-7	10-4	9-9	9-6	9-11	9-9	9-9	9-3	9-0	8-8	9-3	9-0
ROOF DECKING - 10 psf Dead Load / 20 psf Live Load (seven-day load) — L/240 Deflection Limit																								
Simple	8-9	8-7	8-1	7-10	8-3	8-1	8-1	7-8	7-5	7-3	7-8	7-5	14-7	14-4	13-5	13-1	13-9	13-5	13-5	12-9	12-5	12-0	12-9	12-5
Controlled Random	9-7	9-5	8-10	8-7	9-0	8-10	8-10	8-4	8-2	7-10	8-4	8-2	16-9	16-5	15-5	15-1	15-9	15-5	15-5	14-8	14-3	13-9	14-8	14-3
ROOF DECKING - 10 psf Dead Load / 30 psf Live Load (snow load) — L/240 Deflection Limit																								
Simple	7-8	7-6	7-1	6-11	7-3	7-1	7-1	6-8	6-6	6-4	6-8	6-6	12-9	12-6	11-9	11-6	12-0	11-9	11-9	11-2	10-10	10-6	11-2	10-10
Controlled Random	8-4	8-3	7-8	7-6	7-10	7-8	7-8	7-4	7-1	6-11	7-4	7-1	14-8	14-5	13-6	13-2	13-9	13-6	13-6	12-10	12-5	12-1	12-10	12-5
ROOF DECKING - 10 psf Dead Load / 40 psf Live Load (snow load) — L/240 Deflection Limit																								
Simple	7-0	6-10	6-5	6-3	6-7	6-5	6-5	6-1	5-11	5-9	6-1	5-11	11-7	11-5	10-8	10-5	10-11	10-8	10-8	10-2	9-10	9-6	10-2	9-10
Controlled Random	7-7	7-6	7-0	6-10	7-2	7-0	7-0	6-8	6-5	6-3	6-8	6-5	13-4	13-1	12-3	11-11	12-6	12-3	12-3	11-8	11-4	10-11	11-8	11-4

Spans for Dimension Lumber (8" & narrower) run-to-pattern as 2" and 3" decking may be used as follows:

No. 2 Grade

- DF-L uses spans for Hem-Fir Selected Decking.
- DF-S uses spans for Western Woods Selected Decking.
- H-F uses spans for Douglas Fir-South Commercial Decking.
- SPFS uses spans for Western Woods Commercial Decking.
- Other species groups use spans for Western Cedars Commercial Decking.

No. 3 Grade (for Roof Decking: use Simple arrangement spans for both Simple and Controlled Random arrangements.)

- DF-L uses spans for Douglas Fir-South Selected Decking.
- DF-S uses spans for Western Cedars Selected Decking.
- H-F uses spans for Western Woods Selected Decking.
- SPFS uses spans for Western Cedars Commercial Decking with reductions of 3" for 2" -Decking, and 5" for 3" -Decking

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4.1.8 Sizes, Properties of Dressed Western Lumber Species

Framing Lumber

PROPERTIES OF STANDARD DRESSED SIZES (S4S)

Certain mathematical expressions of the properties or elements of sections are used in computing the values of structural members of various shapes for the various conditions under which they are subjected to stress. The properties or elements of sections of standard sizes of joists, planks, beams, stringers, posts, timbers and decking are given in the following tables.

NEUTRAL AXIS, X–X in the diagrams, in the cross section of a beam or column in a state of flexure, is the line on which there is neither tension nor compression.

In the following tables, which show the properties of the rectangular and square sections of lumber, the neutral axis has been assumed as perpendicular to the depth of the section at its center, the depth "h" being parallel to and in the direction of the application of the force or load.

MOMENT OF INERTIA, *I*, of the cross section of a beam is the sum of the products of each of its elementary areas by the square of their distance from the neutral axis of the section.

SECTION MODULUS, *S*, is the moment of inertia divided by the distance from the neutral axis to the extreme fiber of the section.

CROSS SECTION is a section taken through the member perpendicular to its longitudinal axis.

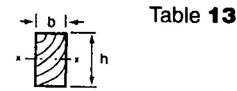
SECTION PROPERTIES OF PLANKS Table **11**

Nominal Size in Inches $b \times h$	Surfaced Size for Design in Inches $b \times h$	Area (*A*) $A = bh$ (in²)	Section Modulus (*S*) $S = \frac{bh^2}{6}$ (in³)	Moment of Inertia (*I*) $I = \frac{bh^3}{12}$ (in⁴)	Board Feet per Lineal Foot of Piece
3 × 2	2.5 × 1.5	3.75	0.938	0.703	0.50
4 × 2	3.5 × 1.5	5.25	1.312	0.984	0.67
6 × 2	5.5 × 1.5	8.25	2.062	1.547	1.00
8 × 2	7.25 × 1.5	10.88	2.719	2.039	1.33
10 × 2	9.25 × 1.5	13.88	3.469	2.602	1.67
12 × 2	11.25 × 1.5	16.88	4.219	3.164	2.00
4 × 3	3.5 × 2.5	8.75	3.646	4.557	1.00
6 × 3	5.5 × 2.5	13.75	5.729	7.161	1.50
8 × 3	7.25 × 2.5	18.12	7.552	9.440	2.00
10 × 3	9.25 × 2.5	23.12	9.635	12.044	2.50
12 × 3	11.25 × 2.5	28.12	11.719	14.648	3.00
14 × 3	13.25 × 2.5	33.12	13.802	17.253	3.50
16 × 3	15.25 × 2.5	38.12	15.885	19.857	4.00
6 × 4	5.5 × 3.5	19.25	11.229	19.651	2.00
8 × 4	7.25 × 3.5	25.38	14.802	25.904	2.67
10 × 4	9.25 × 3.5	32.38	18.885	33.049	3.33
12 × 4	11.25 × 3.5	39.38	22.969	40.195	4.00
14 × 4	13.25 × 3.5	46.38	27.052	47.341	4.67
16 × 4	15.25 × 3.5	53.38	31.135	54.487	5.33

SECTION PROPERTIES OF DECKING (per foot of width) Table **12**

Nominal Size in Inches *h*	Surfaced Size for Design in Inches $b \times h$	Area (*A*) $A = bh$ (in²)	Section Modulus (*S*) $S = \frac{bh^2}{6}$ (in³)	Moment of Inertia (*I*) $I = \frac{bh^3}{12}$ (in⁴)	Board Feet per Lineal Foot of Piece
2	12 × 1.5	18.00	4.50	3.375	2.00
3	12 × 2.5	30.00	12.50	15.625	3.00
4	12 × 3.5	42.00	24.50	42.875	4.00

SECTION PROPERTIES OF JOISTS AND BEAMS Table **13**



Nominal Size in Inches $b \times h$	Surfaced Size for Design in Inches $b \times h$	Area (*A*) $A = bh$ (in²)	Section Modulus (*S*) $S = \frac{bh^2}{6}$ (in³)	Moment of Inertia (*I*) $I = \frac{bh^3}{12}$ (in⁴)	Board Feet per Lineal Foot of Piece
2 × 2	1.5 × 1.5	2.25	0.562	0.422	0.33
2 × 3	1.5 × 2.5	3.75	1.56	1.95	0.50
2 × 4	1.5 × 3.5	5.25	3.06	5.36	0.67
2 × 6	1.5 × 5.5	8.25	7.56	20.80	1.00
2 × 8	1.5 × 7.25	10.88	13.14	47.63	1.33
2 × 10	1.5 × 9.25	13.88	21.39	98.93	1.67
2 × 12	1.5 × 11.25	16.88	31.64	177.98	2.00
2 × 14	1.5 × 13.25	19.88	43.89	290.78	2.33
3 × 3	2.5 × 2.5	6.25	2.60	3.26	0.75
3 × 4	2.5 × 3.5	8.75	5.10	8.93	1.00
3 × 6	2.5 × 5.5	13.75	12.60	34.66	1.50
3 × 8	2.5 × 7.25	18.12	21.90	79.39	2.00
3 × 10	2.5 × 9.25	23.12	35.65	164.89	2.50
3 × 12	2.5 × 11.25	28.12	52.73	296.63	3.00
3 × 14	2.5 × 13.25	33.12	73.15	484.63	3.50
3 × 16	2.5 × 15.25	38.12	96.90	738.87	4.00
4 × 4	3.5 × 3.5	12.25	7.15	12.51	1.33
4 × 6	3.5 × 5.5	19.25	17.65	48.53	2.00
4 × 8	3.5 × 7.25	25.38	30.66	111.15	2.67
4 × 10	3.5 × 9.25	32.38	49.91	230.84	3.33
4 × 12	3.5 × 11.25	39.38	73.83	415.28	4.00
4 × 14	3.5 × 13.25	46.38	102.41	678.48	4.67
4 × 16	3.5 × 15.25	53.38	135.66	1034.42	5.33
6 × 6	5.5 × 5.5	30.25	27.73	76.26	3.00
6 × 8	5.5 × 7.5	41.25	51.56	193.36	4.00
6 × 10	5.5 × 9.5	52.25	82.73	392.96	5.00
6 × 12	5.5 × 11.5	63.25	121.23	697.07	6.00
6 × 14	5.5 × 13.5	74.25	167.06	1127.67	7.00
6 × 16	5.5 × 15.5	85.25	220.23	1706.78	8.00
6 × 18	5.5 × 17.5	96.25	280.73	2456.38	9.00
6 × 20	5.5 × 19.5	107.25	348.56	3398.48	10.00
8 × 8	7.5 × 7.5	56.25	70.31	263.67	5.33
8 × 10	7.5 × 9.5	71.25	112.81	535.86	6.67
8 × 12	7.5 × 11.5	86.25	165.31	950.55	8.00
8 × 14	7.5 × 13.5	101.25	227.81	1537.73	9.33
8 × 16	7.5 × 15.5	116.25	300.31	2327.42	10.67
8 × 18	7.5 × 17.5	131.25	382.81	3349.61	12.00
8 × 20	7.5 × 19.5	146.25	475.31	4634.30	13.33
8 × 22	7.5 × 21.5	161.25	577.81	6211.48	14.67
8 × 24	7.5 × 23.5	176.25	690.31	8111.17	16.00
10 × 10	9.5 × 9.5	90.25	142.90	678.76	8.33
10 × 12	9.5 × 11.5	109.25	209.40	1204.03	10.00
10 × 14	9.5 × 13.5	128.25	288.56	1947.80	11.67
10 × 16	9.5 × 15.5	147.25	380.40	2948.07	13.33
10 × 18	9.5 × 17.5	166.25	484.90	4242.84	15.00
10 × 20	9.5 × 19.5	185.25	602.06	5870.11	16.67
10 × 22	9.5 × 21.5	204.25	731.90	7867.88	18.33
12 × 12	11.5 × 11.5	132.25	253.48	1457.51	12.00
12 × 14	11.5 × 13.5	155.25	349.31	2357.86	14.00
12 × 16	11.5 × 15.5	178.25	460.48	3568.71	16.00
12 × 18	11.5 × 17.5	201.25	586.98	5136.07	18.00
12 × 20	11.5 × 19.5	224.25	728.81	7105.92	20.00
12 × 22	11.5 × 21.5	247.25	885.98	9524.28	22.00
12 × 24	11.5 × 23.5	270.25	1058.48	12437.13	24.00

Used courtesy of Western Wood Products Assn.

4.1.9 Appearance Lumber—Definition and Uses

Appearance Lumber

The lumber grades in this category are intended for applications where strength is not the primary consideration. Grading is by visual inspection and is a judgment of appearance and suitability to end use rather than of strength. Natural characteristics and manufacturing imperfections are taken into account in the assigning of grades. Lumber in this category is often generically referred to as Board lumber, although the category also includes run-to-pattern products and Patio Decking. The highest grades of Appearance lumber are seldom gradestamped, unless on the back or ends, as the grade stamp would deface the product. The general purpose grades, such as COMMONS and ALTERNATE BOARDS, are generally stamped. Refer to page 20 for additional information on grade stamps, moisture content and specifying Appearance lumber.

Many of the Western lumber species are grown, harvested, manufactured and shipped together in "Marketing Categories." In addition to the species combinations that share like structural characteristics, Board lumber is often available in combinations related to like appearance characteristics. Refer to the Marketing Categories species list on page 4 and the WWPA *Western Lumber Grading Rules* for additional information.

The grades and recommended end uses for Appearance lumber are explained in Table 14. Standard sizes are explained in Table 15. Refer to page 19 for information on the Radius-edged Patio Decking grades.

APPEARANCE LUMBER GRADES Table **14**

	Product	Grades[1]	Equivalent Grades in Idaho White Pine	WWPA Grading Rules Section Number
Highest Quality Appearance Grades	Selects *(all species)*	B & BTR SELECT C SELECT D SELECT	SUPREME CHOICE QUALITY	10.11 10.12 10.13
	Finish *(usually available only in Doug Fir and Hem-Fir)*	SUPERIOR PRIME E		10.51 10.52 10.53
	Special Western Red Cedar Pattern[2] Grades	CLEAR HEART A GRADE B GRADE		20.11 20.12 20.13
General Purpose Grades	Common Boards (WWPA Rules) *(primarily in pines, spruces, and cedars)*	1 COMMON 2 COMMON 3 COMMON 4 COMMON 5 COMMON	COLONIAL STERLING STANDARD UTILITY INDUSTRIAL	30.11 30.12 30.13 30.14 30.15
	Alternate Boards (WCLIB Rules) *(primarily in Doug Fir and Hem-Fir)*	SELECT MERCHANTABLE CONSTRUCTION STANDARD UTILITY ECONOMY		WCLIB[3,4] 118-a 118-b 118-c 118-d 118-e
	Special Western Red Cedar Pattern[2] Grades	SELECT KNOTTY QUALITY KNOTTY		WCLIB[3] 111-e 111-f

[1] Refer to WWPA's *Vol 2, Western Wood Species* book for full-color photography and to WWPA's *Natural Wood Siding* for complete information on siding grades, specification and installation.
[2] "PATTERN" includes finish, paneling, ceiling and siding grades.
[3] West Coast Lumber Inspection Bureau's *West Coast Lumber Standard Grading Rules*.
[4] Also found in WWPA's *Western Lumber Grading Rules*.

BOARD LUMBER

Grades/End Uses - Select grades are determined from the better side or face and are used for applications where only the finest appearance is appropriate. B & BTR is virtually clear and very limited in availability. The appearance of C SELECT ranks only slightly less than B & BTR SELECT. D SELECT is suitable where the requirements for finishing are less exacting.

Finish grades are determined from the better side or face and from both edges on pieces 5" and narrower and from the better side or face and one edge on pieces 6" and wider. SUPERIOR is virtually clear. PRIME grade exhibits fine appearance although slightly less restrictive than SUPERIOR. E grade is intended for ripping and cross-cutting to obtain small pieces of PRIME or better quality.

The highest quality, premium cedar grades are typically run-to-pattern into siding or paneling products and may be graded to either the surfaced or a saw-textured side. CLEAR VG HEART is intended for use where only the highest quality is indicated. The exposed width is all heartwood and free from imperfections. A grade allows only minor imperfections and is of fine appearance. Square-edged cedar boards are generally manufactured in SELECT grades.

Common Board grades are determined from the better face and are varying qualities of knotty material. 1 and 2 COMMON are usually sold as 2 & BTR COMMON and intended for paneling, shelving and other uses where a fine appearance in knotty material is desirable. 3 COMMON is also widely used for siding, paneling and shelving as well as for fences, boxes, crating, sheathing and industrial applications.
4 COMMON is used for general construction such as subfloors, roof and wall sheathing, concrete forms, low-cost fencing and crating.
5 COMMON is intended for economy-governed applications.

Alternate Board grades are determined from the better face. SELECT MERCHANTABLE is intended for use in housing and light construction where it is exposed as paneling, shelving and where knotty type lumber of fine appearance is desirable. CONSTRUCTION is used for spaced sheathing, let-in bracing, fences, boxes, crating and industrial applications. The uses for STANDARD are similar to a 4 COMMON, as described above.

Special Western Red Cedar general purpose grades (SELECT KNOTTY or QUALITY KNOTTY) are similar in appearance to 2 COMMON and 3 COMMON, and are widely used for siding and landscape applications. Knot size and quality are defined in the grading rules; sound, tight knots do not adversely affect performance. Dry knotty siding must not exceed 19% moisture content and it may be specified to MC15 or KD15. Knotty siding also is sometimes manufactured unseasoned.

RUN-TO-PATTERN PRODUCTS

Board lumber is the starting material for many products that are run-to-pattern, such as paneling, siding, flooring, ceiling and partition material. In many cases, the grade of the material that has been run-to-pattern reflects the grade of the starting material, adhering to similar requirements for allowable characteristics.

Refer to WWPA's *Natural Wood Siding-Technical Guide* (TG-8) for comprehensive information on WWPA and WCLIB siding grades, patterns, specification and installation. Refer to WWPA's *Standard Patterns* (G-16) for paneling, flooring, ceiling, partition (and siding) patterns in profile with dimensions. Contact the Wood Moulding and Millwork Producers Association (**www.wmmpa.com**) for moulding and trim patterns in profile.

4.1.10 Radius-Edged Patio Decking Appearance Western Lumber

Appearance Lumber

RADIUS-EDGED PATIO DECKING

Grades/End-Uses - Western Patio Decking is manufactured to be used flat-wise for load-bearing applications where spans are maximum 16" on center. Ponderosa Pine species graded to the WWPA rules for Patio Decking is span rated for 24" on center. This product offers an excellent option for decks and landscaping applications where Structural Decking or other dimension products would not be sufficiently refined in appearance to suit the end use.

Its thin profile, with oversized eased edges, makes it suitable for outdoor and garden applications such as patio decks, benches, railings, trim and fencing. It may be used for planters and shelving where stock thinner than regular 2" decking is desirable.

Patio Decking is available in two grades: PATIO 1 and PATIO 2.

PATIO 1 is similar in appearance (in terms of limitations on natural characteristic but allowing fewer restrictions with regards to manufacturing imperfections) to a 2 & BTR COMMON; whereas PATIO 2 is similar in appearance to the upper end of the 3 COMMON. Refer to page 18 for a description of the COMMON grades.

Patio Decking is manufactured primarily in Ponderosa Pine (which has a cell structure very receptive to preservative pressure treating) and the Western Cedars (which are naturally durable). The Patio grades are gradually becoming available in other Western lumber species as well.

Both grades may be manufactured in two sizes. Refer to Table 16.

Nailing - Pre-drill holes near the ends of each piece. Use only non-corrosive (stainless steel, high strength aluminum or hot-dipped galvanized) 10d (3") nails or 8d (minimum) deck screws. Use two nails per piece driven one inch in from each edge. Ring- or spiral-shank nails will provide additional holding capacity. Pre-finish edges, ends and surfaces for best results.

Refer to "Seasoning Lumber" on page 20 for additional information.

STANDARD SIZES PATIO DECKING — Table **16**

PATIO 1 & 2	Surfaced DRY	Surfaced GRN
$\frac{1}{4}$" radius edge	1" × $5\frac{1}{2}$"	$1\frac{1}{32}$" × $5\frac{5}{8}$"
$\frac{3}{8}$" radius edge	$1\frac{5}{32}$" × $5\frac{1}{2}$"	$1\frac{3}{16}$" × $5\frac{5}{8}$"

STANDARD SIZES - APPEARANCE LUMBER — Table **15**

Nominal & Dressed (Based on *Western Lumber Grading Rules*)

		Nominal Size		Dry Dressed (surfaced) Size				
		Thickness	Width	Thickness		Width		Lengths
Product	Description	inch	inch	inch	mm	inch	mm	feet
SELECTS AND COMMONS	S1S, S2S, S4S, S1S1E, S1S2E	4/4	2	$\frac{3}{4}$	19	$1\frac{1}{2}$	38	6' (183 cm) and longer in multiples of 1' (31 cm), except Douglas Fir and Larch Selects shall be 4' (122 cm) and longer with 3% of 4' (122 cm) and 5' (152 cm) permitted.
		5/4	3	$1\frac{5}{32}$	29	$2\frac{1}{2}$	64	
		6/4	4	$1\frac{13}{32}$	36	$3\frac{1}{2}$	89	
		7/4	5	$1\frac{19}{32}$	40	$4\frac{1}{2}$	114	
		8/4	6	$1\frac{13}{16}$	46	$5\frac{1}{2}$	140	
		9/4	7	$2\frac{3}{32}$	53	$6\frac{1}{2}$	165	
		10/4	8 & wider	$2\frac{3}{8}$	60	$\frac{3}{4}$ off nominal	19 off nominal	
		11/4		$2\frac{9}{16}$	65			
		12/4		$2\frac{3}{4}$	70			
		16/4		$3\frac{3}{4}$	95			
FINISH AND ALTERNATE BOARD GRADES	S1S, S2S, S4S, S1S1E, S1S2E	$\frac{3}{8}$	2	$\frac{5}{16}$	8	$1\frac{1}{2}$	38	3' (91 cm) and longer. In SUPERIOR grade, 3% of 3' (91 cm) and 4' (122 cm) and 7% of 5' (152 cm) and 6' (183 cm) are permitted. In PRIME grade 20% of 3' (91 cm) to 6' (183 cm) is permitted.
		$\frac{1}{2}$	3	$\frac{7}{16}$	11	$2\frac{1}{2}$	64	
		$\frac{5}{8}$	4	$\frac{9}{16}$	14	$3\frac{1}{2}$	89	
		$\frac{3}{4}$ [1]	5	$\frac{5}{8}$	16	$4\frac{1}{2}$	114	
		1 [1]	6	$\frac{3}{4}$	19	$5\frac{1}{2}$	140	
		$1\frac{1}{4}$ [1]	7	1	25	$6\frac{1}{2}$	165	
		$1\frac{1}{2}$ [1]	8 & wider	$1\frac{1}{4}$	32	$\frac{3}{4}$ off nominal	19 off nominal	
		$1\frac{3}{4}$		$1\frac{3}{8}$	35			
		2		$1\frac{1}{2}$	38			
		$2\frac{1}{2}$		2	51			
		3		$2\frac{1}{2}$	64			
		$3\frac{1}{2}$		3	76			
		4		$3\frac{1}{2}$	89			

[1] These sizes apply only to WCLIB Alternate Board grades.

Abbreviations:
S1S—Surfaced one side
S2S—Surfaced two sides
S4S—Surfaced four sides
S1S1E—Surfaced one side, one edge
S1S2E—Surfaced one side, two edges

Note on Metrics: Metric equivalents are provided for surfaced (actual) sizes.

4.1.11 Specifying Finish Carpentry Materials

Appearance Lumber

SPECIFYING FINISH CARPENTRY MATERIALS

A specification for a Finish or Board lumber grade should include a reference to the section number, title and edition of the grading rules from which it is written. In other words, if specifying from Section 21.11, Special Western Red Cedar Rules, WWPA *Western Lumber Grading Rules 05*, so state.

Grain patterns, when desired, can also be specified for Selects, Finish and Special Western Red Cedar grades. Three categories are available: vertical grain (VG), flat grain (FG) or a shipment of both VG and FG, generally referred to as mixed grain (MG). The most readily available and least costly is mixed grain. Unless otherwise specified, siding, paneling and finish boards are shipped with mixed grain. Stair treads and stepping should be vertical grain as it is more durable.

Board Lumber in Combination with Rough Carpentry Materials - Boards, basically, are 1" nominal thickness. Board grades used in conjunction with rough carpentry materials are generally controlled by building code requirements, and the grades are selected from the Common or Alternate Board grades listed in the appearance lumber grades chart in Table 14, page 18.

As an example, major model building codes recognize 3 COMMON or STANDARD grades as equal minimum grades for spaced roof sheathing even though there are differences in grading characteristics. Verify local building code requirements and dealer availability prior to specifying.

Seasoning Lumber - Once in place, lumber adjusts to its surrounding atmospheric conditions. In a covered structure, lumber will stabilize at approximately 6% to 12% moisture content. Size will vary approximately 1% for each 4% change in moisture content. Thus, it is important that all finish materials be stacked and stickered, in the room where they will be applied, for 7 to 10 days prior to installation.
2x decking material should be allowed to acclimate for 14 to 21 days prior to installation. The lumber should be stored off the ground, well ventilated and loosely covered. The lumber will then stabilize its moisture content for its permanent location. Staining or priming, where economically feasible, should be done before installation. Refer to WWPA's *Paneling Basics* (A-3), *Natural Wood Siding-Technical Guide* (TG-8) and *Lumber Storage* (TG-5) for additional information.

Moisture Content - WWPA Finish, Select and Special Western Red Cedar Grades are shipped seasoned as follows: S-DRY (or KD) or MC15 (or KD15) with at least 85 percent of items not exceeding 12% in moisture content and no portion exceeding 15% moisture content. Appearance grades of Western lumber are not shipped S-GRN (with a moisture content above 19% at the time of surfacing) except in some of the knotty grades. Refer to page 5 for additional information on moisture content designations in the grade stamp and to WWPA's *Natural Wood Siding-Technical Guide* (TG-8) for recommendations on handling unseasoned siding products.

Interior and Exterior Trim and Finish Board Materials - Select from appearance grades as indicated in Table 14, page 18, and described in the WWPA *Western Lumber Grading Rules*.

Refer to the WWPA publication *Vol. 2: Western Wood Species* (11) for color photographs of Select, Finish, Common and Alternate Board grades in many Western lumber species.

Wood Siding and Paneling Materials - The publications *Natural Wood Siding–Technical Guide* (TG-8) and *Paneling Basics* (A-3) offer information on selecting pattern type and grade, and summarize installation and handling requirements.

After a general pattern type has been selected, the pattern number should be specified from the WWPA publication *Standard Patterns* (G-16).

When a saw-textured face is desired, the face to be textured and the type of texture (band sawn, rough sawn, circular sawn) should be specified.

A siding specification should include WWPA's industry recommendations for acclimatization, backpriming, nailing and finishing. Refer to WWPA's *Natural Wood Siding–Technical Guide* (TG-8) for details. A checklist and moisture content guidelines are provided below for convenience.

MOISTURE CONTENT GUIDELINES

Uses of Wood	Recommended Moisture Content at Time of Installation[1]					
	Most Areas of the U.S.		Dry, Southwestern States		Damp, Warm South-eastern Coastal Areas	
	Average[1]	Individual Pieces	Average[1]	Individual Pieces	Average[1]	Individual Pieces
Interior: Furniture, Woodwork, Flooring and Wood Trim	8%	6-10%	6%	4-9%	11%	8-13%
Exterior: Siding, Trim, Sheathing and Laminated Timbers	12%	9-14%	9%	7-12%	12%	9-14%

[1] To obtain a realistic average, test at least 10% of each item, i.e. 10% of the siding pieces, 10% of the trim pieces and random checks of the sheathing material. It is particularly important to check the sheathing prior to the siding application if it has become wet after it was installed.

Source: USDA Wood Handbook, 1999, Table 12-2, Forest Products Laboratory Report FPL-GTR-113.

SIDING OR PANELING MATERIAL SPECIFICATION — Checklist 6

- ☐ Select species suited to the project.
- ☐ List grade names, paragraph numbers and rules-writing agency. *(Refer to Table 14.)*
- ☐ Specify surface texture for exposed face.
- ☐ Specify moisture content suited to project.
- ☐ If gradestamped, specify lumber be stamped on back or ends. (WWPA's *Specifying Lumber* [A-2] offers additional information.)
- ☐ Specify VG (vertical grain) if appropriate and available.
- ☐ Specify pattern and size. (WWPA's *Standard Patterns* [G-16] offers additional information.)
- ☐ Specify installation, nailing and finishing. (WWPA's *Natural Wood Siding-Technical Guide* [TG-8] offers additional information.)

4.1.12 Notching, Boring Guidelines for Floor Joints and Stud Walls

NOTCHING & BORING GUIDE FOR
FLOOR JOISTS & STUD WALLS IN
CONVENTIONAL LIGHT-FRAME CONSTRUCTION

Notching & Boring Guidelines

Intended for use by residential builders, this WWPA TIP Sheet serves as a guide to code-allowed size and placement of cuts (notching and boring) in floor-joist and stud-wall framing members.

A number of problems can occur if cuts are made through framing members to make room for plumbing or electrical runs, ductwork, or other mechanical elements such as sound or security systems.

Whenever a hole or notch is cut into a member, the structural capacity of the piece is weakened and a portion of the load supported by the cut member must be transferred properly to other joists.

It is best to design and frame a project to accommodate mechanical systems from the outset, as notching and boring should be avoided whenever possible; however, unforeseen circumstances sometimes arise during construction.

If it is necessary to cut into a framing member, the following diagrams provide a guide for doing so in the least destructive manner.

Diagrams comply with the requirements of the three major model building codes: Uniform (UBC), Standard (SBC), and National (BOCA), and the CABO One- & Two-Family Dwelling Code.

FLOOR JOISTS

The following references are to actual, not nominal dimensions. (See Figure 1: *Placement of Cuts in Floor Joists* and Table 1*: Maximum Sizes for Cuts in Floor Joists.)*

Holes: Do not bore holes closer than 2" from joist edges, nor make them larger than 1/3 the depth of the joist.

Notches: Do not make notches in the middle third of the span where the bending forces are greatest. Notches should be no deeper than 1/6 the depth of the joist. Notches at the end of the joist should be no deeper than 1/4 the depth. Limit the length of notches to 1/3 of the joist's depth.

When a Notch Becomes a Rip

Codes do not address the maximum allowable length of a notch; however, the 1991 *National Design Specification (NDS)* does limit the maximum length of a notch to 1/3 the depth of a member.

It is important to recognize the point at which a notch becomes a rip, such as when floor joists at the entry of a home are ripped down to allow underlayment for a tile floor.

Ripping wide dimension lumber lowers the grade of the material, and is unacceptable under all building codes.

When a sloped surface is necessary, a non-structural member can be ripped to the desired slope and fastened to the structural member in a position above the top edge. Do not rip the structural member.

STUD WALLS

When structural wood members are used vertically to carry loads in compression, the same engineering procedure is used for both studs and columns. However, differences between studs and columns are recognized in the model building codes for conventional light-frame residential construction.

The term "column" describes an individual major structural member subjected to axial compression loads, such as columns in timber-frame or post-and-beam structures.

The term "stud" describes one of the members in a wall assembly or wall system carrying axial compression loads, such as 2x4 studs in stud wall that includes sheathing or wall board. The difference between columns and studs can be further described in terms of the potential consequences of failure.

Columns function as individual major structural members, consequently failure of a column is likely to result in partial collapse of a structure (or complete collapse in extreme cases due to the domino effect). However, studs function as members in a system. Due to the system effects (load sharing, partial composite action, redundancy, load distribution, etc.), studs are much less likely to fail and result in a total collapse than are columns.

Notching or boring into columns is not recommended and rarely acceptable; however, model codes establish guidelines for allowable notching and boring into studs used in a stud-wall system.

Figures 2 and 3 illustrate the maximum allowable notching and boring of 2x4 studs under all model codes except BOCA. BOCA allows a hole one third the width of the stud in all cases.

Bored holes shall not be located in the same cross section of a stud as a cut or notch.

For additional information on framing (and common framing errors), contact WWPA for reprints of the following articles written by Association field staff.

Field Guide to Common Framing Errors (JLC-2) reprinted from *Journal of Light Construction*: article focuses on most commonly-encountered job-site errors. 6 pgs.

Common Roof-Framing Errors (JLC-3) reprinted from *Journal of Light Construction:* focuses on problems and solutions with trusses, rafters, collar

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4.1.12 Notching, Boring Guidelines for Floor Joints and Stud Walls (Continued)

Table 1: Maximum Sizes for Cuts in Floor Joists

Joist Size	Max. Hole	Max Notch Depth	Max. End Notch
2x4	none	none	none
2x6	1-1/2"	7/8"	1-3/8"
2x8	2-3/8"	1-1/4"	1-7/8"
2x10	3"	1-1/2"	2-3/8"
2x12	3-3/4"	1-7/8"	2-7/8"

Fig. 1: Placement of Cuts in Floor Joists

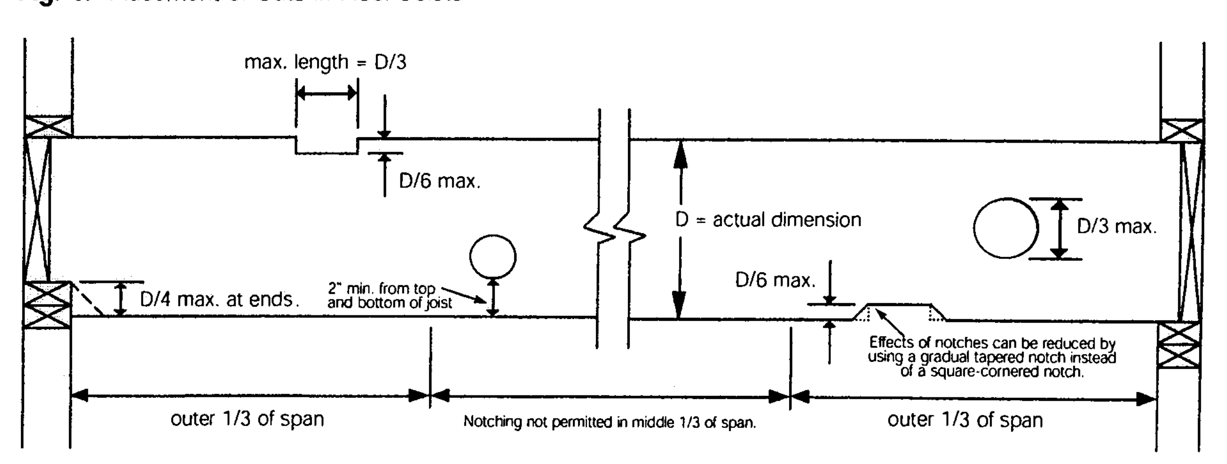


Fig. 2: Notches in 2x4 Studs

3-1/2" — 7/8" max. — 25%* allowed in exterior and bearing walls

3-1/2" — 1-7/16" max. — 40%* allowed in any non-bearing wall

Fig. 3: Bored Holes in 2x4 Studs

3-1/2" — 1-7/16" — 5/8" min. — 40%* allowed in any wall

3-1/2" — 2-1/8" — 5/8" min. — 60%* allowed in any non-bearing wall or in bearing walls with not more than two successive studs bored and doubled



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*Figures 2 and 3 illustrate 25%, 40% and 60% notches or holes in 2x4s (e.g. .25 x 3 1/2" = .875 or 7/8"). These percentages apply to studs of any size.

A-11/2017e/8-96, 2-97/15M

4.1.13 Avoiding Common Framing Problems

COMMON FRAMING PROBLEMS AND HOW TO AVOID THEM

Wood-frame homes continue to be the dominant choice for both home buyers and home builders in the U.S. Tens of millions of homes have been constructed with wood framing. Even with this long history of wood-frame construction, there are some framing practices that should be monitored carefully to avoid problems.

This guide is intended to help builders avoid common framing errors that not only cause problems with building inspectors, but may create other difficulties within the structure. These recommendations have been developed through years of work by WWPA with framers, contractors and building code officials.

Frame Openings

One common problem occurs after the basic framing is completed. Subcontractors may cut through floor joists to make room for plumbing runs, ductwork, electrical or other mechanical elements. But often, the load-carrying joists are cut without properly transferring the load to other joists by adding headers.

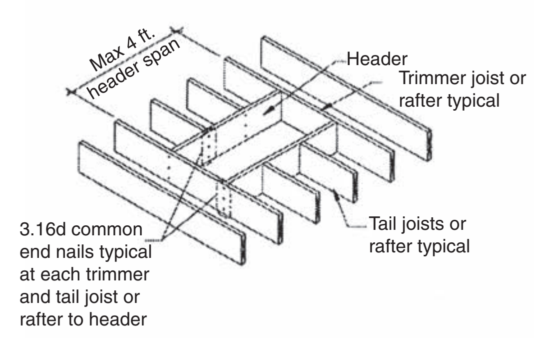


Figure 1A: Basic floor framing for openings

Some openings can be accommodated during the initial framing. Consult the blueprints to see where openings might go and header off any joists that might be in the way in advance. This is often much easier than working from underneath the subfloor later.

Once the framing is up and openings are cut, header joists should be added by end nailing a header across the cut ends of the interrupted joists and to the trimmer joists. This will transfer the load to the adjacent trimmer joists.

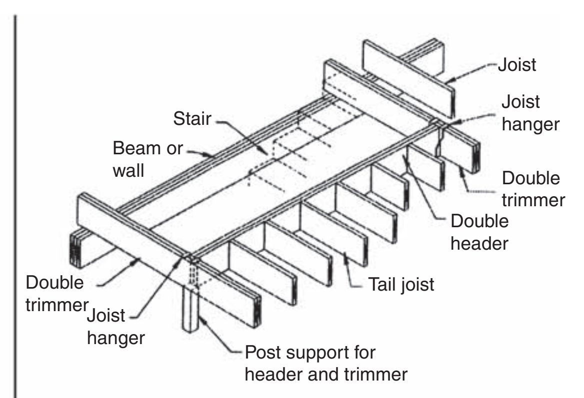


Figure 1B: Opening perpendicular to floor joists

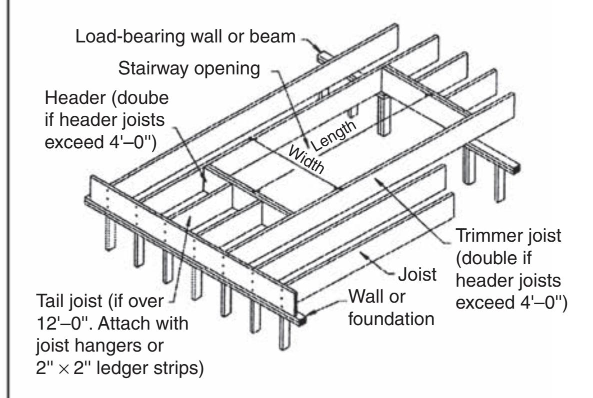


Figure 1C: Opening parallel to floor joists

A single header nailed to the tail and trimmer joists will work for openings less than 4 feet. If the header must span more than 4 feet, both the header and the trimmer joists should be doubled, or of lumber of equivalent cross section. The doubled trimmer and header joists must be nailed together properly (with spaced pairs of 16d nails every 16 inches) so that they act like beams. The doubled header joists can be attached by end nailing for spans up to 6 feet. For spans longer than 6 feet, headers must be supported by joist hangers or framing anchors. Any tail joists over 12 feet long should also be supported at the header by framing anchors or on ledger strips of not less than 2 inches by 2 inches.

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4.1.13 Avoiding Common Framing Problems (Continued)

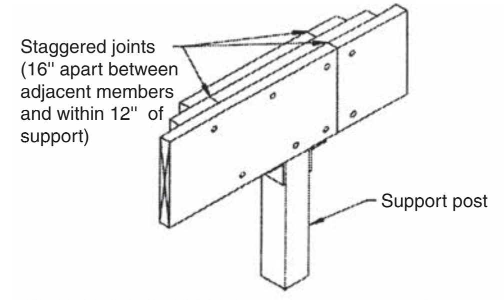


Figure 1D: Staggered joints

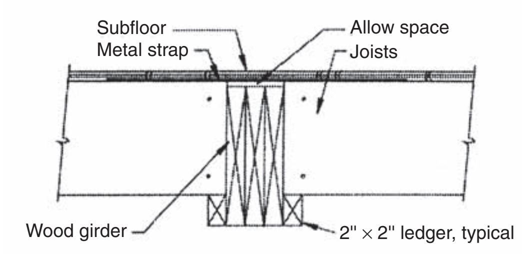


Figure 1E: Supporting joists using ledgers

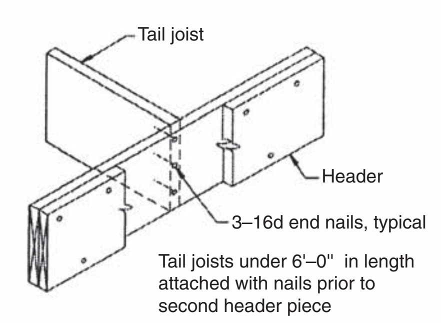


Figure 1F: Nailing tail joists under 6 feet in length

Joist Hangers and Nails

The use of joist hangers has improved the speed and performance of wood-frame construction. For these hangers to work properly, however, they must be correctly sized for the joist they are supporting.

Selecting the right size for a joist hanger is important because of the nailing required for the hanger to support the load. Deeper joists usually carry higher loads and hangers for these joists have more holes for nails. It is the shear strength of the nails that carries much of the load on the hangers, so more nails means a higher load-carrying capacity.

Nail size is important for attaching the hangers. The smallest nail that should be used with joist hangers is a 10d common wire nail. There are specialized nails for attaching joist hangers, which are only 1-1/2 inches long and perform similar to 10d common nails.

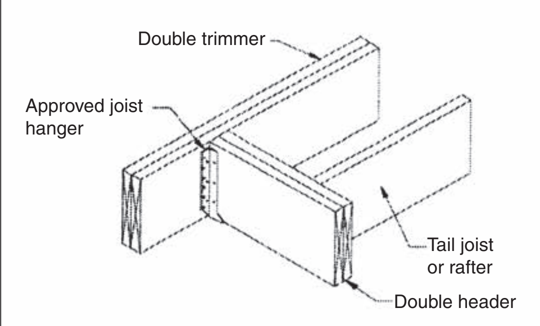


Figure 2a: Joist hanger

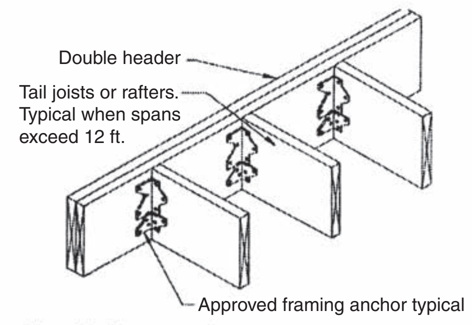


Figure 2b: Framing anchor

For double hangers, use 16d common wire nails. Do not substitute 16d sinker nails for attaching hangers; nail withdrawal strength is also important for attaching hangers and sinker nails can pull out too easily.

Blocking

Incorporating blocking between joists at supports is important – so important that it's required under building codes. The load on any structure must be transferred to the foundation. Joists provide that transfer, as long as they remain upright to receive the loads. Blocking ensures that the joists do not rotate under the heavy loads they are carrying.

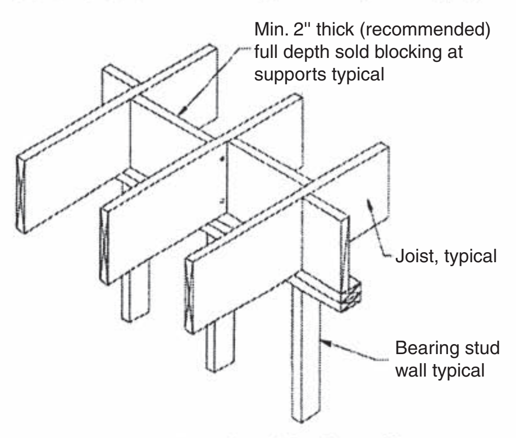


Figure 3: Solid blocking to keep joists from rolling

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4.1.13 Avoiding Common Framing Problems (Continued)

Holes and Notches

While cutting into a load-bearing member should be avoided, there are times when it may be necessary to cut a notch or drill a hole in a joist. Whenever holes or notches exceed the limitations listed below, the lumber is weakened and a portion of the load supported by the cut member must be transferred properly to other joists.

Specifically for floor joists, holes should not be bored closer that 2 inches from a joist edge, nor should they be larger than 1/3 the depth of the joists.

Notches are not allowed in the middle third of the span, where the bending forces are the greatest. Notches should be no deeper than 1/6 the depth of the joist, except at the ends where it can be no deeper than 1/4 the depth. Limit the length of a notch to 1/3 the joist depth.

At times, a notch may be cut so long that it becomes a rip. Unfortunately, ripping wide dimension lumber lowers the grade of the material and is unacceptable under all building codes. When a sloped surface is necessary, a non-structural member can be ripped to the desired slope and fastened to the structural member in a position above the top edge.

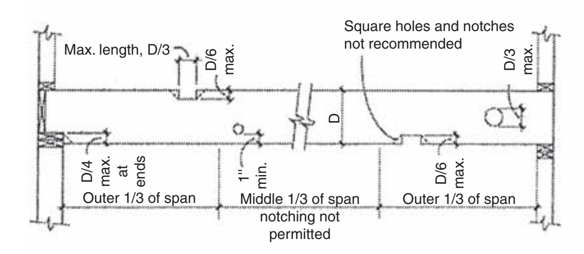


Figure 4: Permitted holes and notches

More information on notching and holes can be found in the WWPA TIP sheet A-11, *Notching & Boring Guide*.

Cantilevers

There is often confusion on how far a conventional cantilever can extend and still support a bearing wall. The old rule of thumb used by builders is to have twice as much joist length anchored in the building as is cantilevered. This rule, however, only applies to non-load bearing walls.

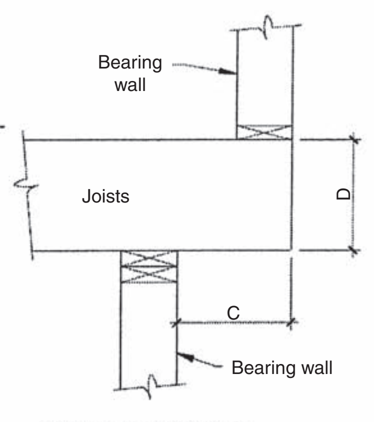


Figure 5: Cantilever limits

For load bearing walls, the maximum distance that joists can be cantilevered (C) without engineering is a distance equal to the depth of the joist (D), see Figure 5. Thus, for a 2x10 joist, the maximum cantilever for a load bearing wall is 9-1/4 inches, the net width of the lumber. Beyond this distance, shear forces and the bending moment at the support can become a problem, eventually causing splitting of the cantilevered joist.

Load Paths

All loads start at the roof and transfer vertically through the building to the foundation. If theses loads are not transferred properly, it can result in the cracking of interior finishes, sagging framing or crushed joists.

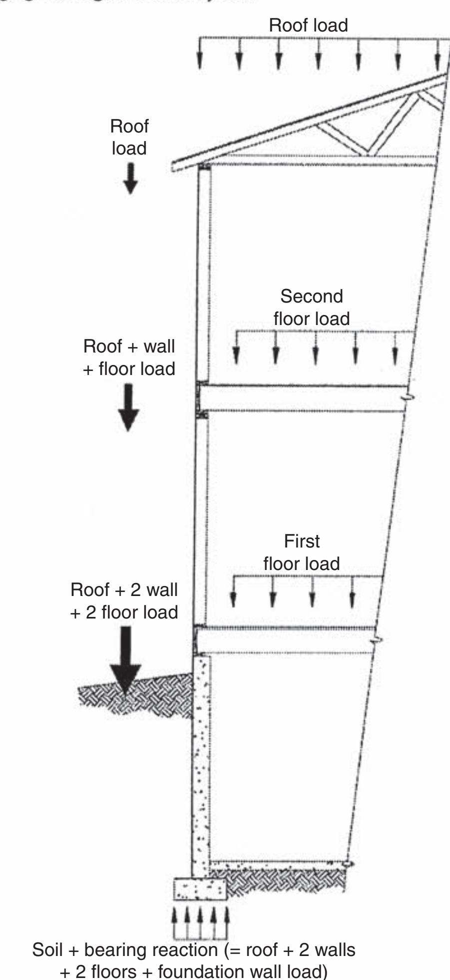


Figure 6A: Vertical load path for gravity loads

Building inspectors pay close attention to broken load paths and will red tag a job when they are encountered in a structure. Problems in transferring loads can be avoided by

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4.1.13 Avoiding Common Framing Problems (Continued)

aligning load bearing walls over supporting beams or walls, proper placement of roof framing and corresponding support struts and transferring column loads directly to the foundation.

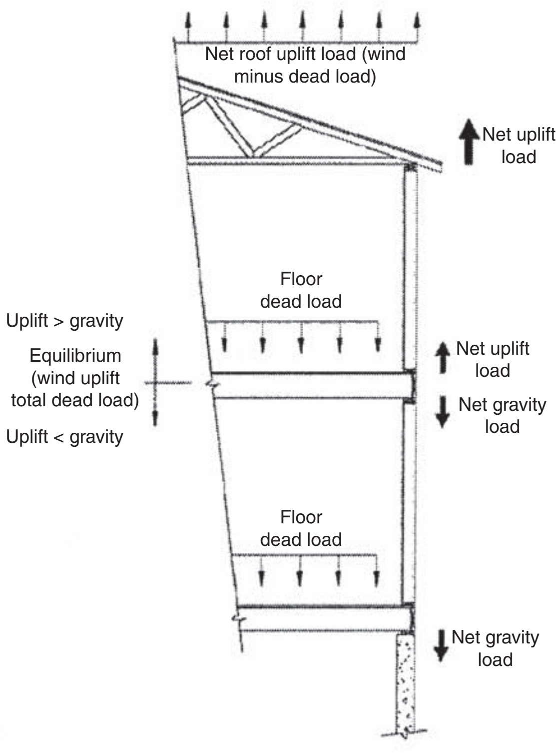


Figure 6B: Load path for wind uplift

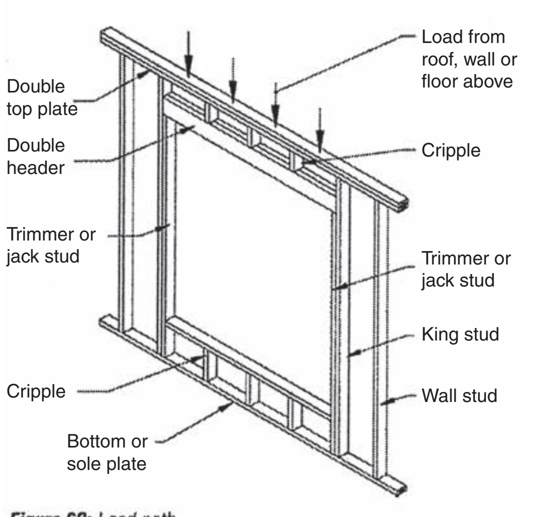


Figure 6C: Load path

Loads carried by bearing walls or posts must be transferred through the floor system. If a bearing wall does not line up with a bearing wall, post or beam below, the floor joists in between can be overstressed and cause severe deflection.

Load bearing walls can be offset from supports below, but only by a distance equal to the depth of the joists. For engineered wood I-joists, the codes require the loads to line up directly over each other and solid blocking or vertical squash-blocks are required to transfer the load around the web of the wood I-joist.

Specific engineered designs of either solid-sawn lumber or I-joists may allow placement of loads at other locations, but discontinuous load paths should not be attempted without consulting an engineer.

Struts are often used to support roof rafters when their lengths exceed the recommended clear spans. These struts should be supported by load bearing partitions or braced to a purlin running across the rafters and should form an angle not less than 45 degrees. Rafter struts should not land on non-load bearing walls or rest on "strong backs," the 2x bracing that runs across ceiling joists.

Columns must bear on elements that can support them. Resting a column on a floor or rim joist without extra blocking or support underneath can crush the underlying joists.

All columns should run continuously to the foundation. If that is not possible, the column should be supported by a beam or header designed to transfer the load to other columns or bearing members. To support a column on a rim joist, add full-depth vertical blocking inside the rim joist to the full depth and width of the column base.

Tapering Joists and Beams

It is sometimes necessary to taper the ends of a beam or joist to keep it under the slope of the roof. But reducing the depth of these members also reduces their load bearing capacity.

If joists must be tapered, make certain the length of the taper cut does not exceed three times the depth of the member and the end of the joist or beam is at least 1/2 the member's original size.

When taper cutting beams, it's also wise to consult a design professional to insure the beam's strength has not been severely reduced. If the tapered beam can't meet the criteria, it will have to be lowered into a beam pocket so that enough cross section can be left, after taper cutting, to carry the applied load.

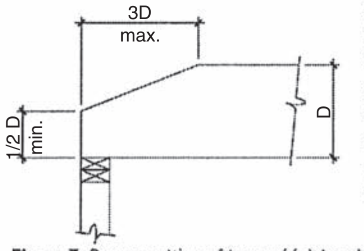


Figure 7: Proper cutting of tapered joist ends

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4.1.13 Avoiding Common Framing Problems (Continued)

Cutting Birdsmouths

Like tapering, cutting a birdsmouth into a rafter reduces the load-carrying capacity of the member. A common error with low-slope rafters is excessive cutting of the rafter seat. This leaves the rafter bearing not on the heel of the seat, as it should, but on the toe. This reduces the effective size of the rafter, producing stresses that can create splits at the bearing point, and eventually, a sagging rafter.

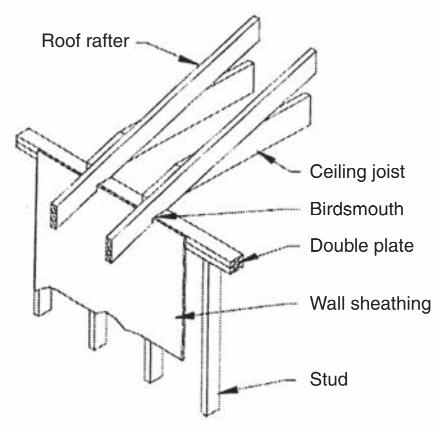


Figure 8: Avoid sagging rafters by properly cutting birdsmouths

Cut the rafters so the heel of the joist becomes the bearing point on the plate. Not only will this maintain the integrity of the joist, it will provide extra inches between the top of the exterior wall and the roof sheathing. This translates into more room for attic insulation to extend over the outside wall, reducing cold spots that can cause condensation or ice dams at the eaves.

Transferring Roof Loads

In today's large houses, the complexity of some roof structures makes it difficult to properly support some of the members. Too often, hips and valleys are unsupported or tied into lower ridges that are also unsupported.

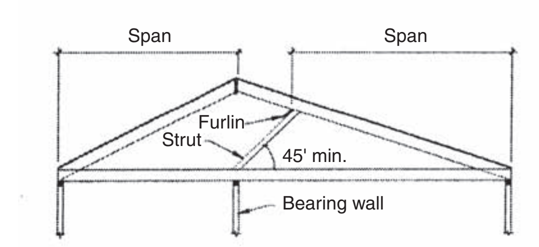


Figure 9: Transfer roof loads using purlins and struts

Hip and valley rafters need to be supported by headers or doubled-up rafters to handle the loads. Headers around openings such as skylights, up to 4 feet long, can be put in square with the rafters. Headers over 4 feet should be put in plumb and its members stepped to follow the slope of the roof. Header rafters more than 6 feet long should be supported by framing anchors. Roof loads are also transferred by the use of purlins and struts that will reduce long rafter spans. Specific requirements for the size and span of purlins, and the size and maximum unbraced length of struts can be found in the conventional construction provisions of the building code.

Rafter Ties and Ridge Beams

Cathedral ceilings are a popular addition to many homes today. But they pose special problems in dealing with the downward force of the rafters that push the exterior walls out. Proper placement of rafter ties and use of structural ridge beams can solve these potential problems, which often result in cracked walls or ceilings and walls out of plumb.

In a conventional wood roof truss, the bottom chord creates a tension tie between the outside walls. For a cathedral ceiling, open rafter ties, or collar ties, can serve the same purpose, provided the ties are placed within the lower 1/3 of the rafter span. The higher the ties go, the less leverage is available to counteract the forces pushing out.

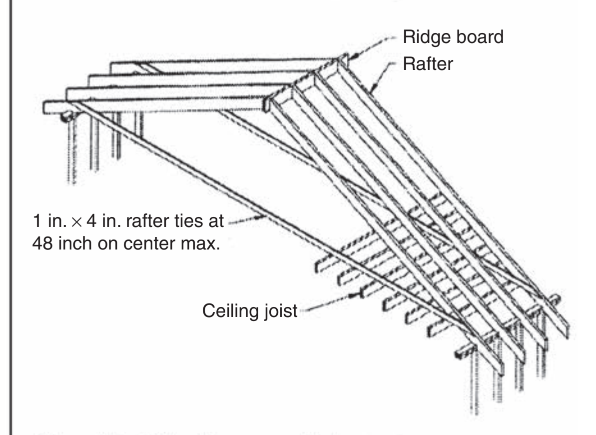


Figure 10A: Ceiling joists perpendicular to rafters

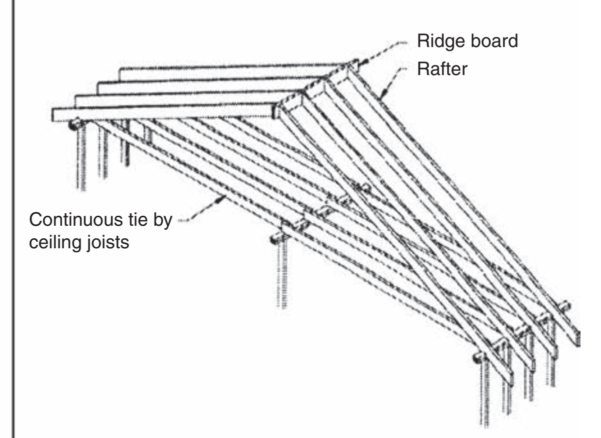


Figure 10B: Ceiling joists parallel to rafters

4.1.14 Thermal Conductivity of Western Softwood Species

THERMAL CONDUCTIVITY OF WESTERN SOFTWOOD SPECIES — Table **25**

Species	k[1]	R/in.
Douglas Fir-Larch	1.06	.94
Douglas Fir-South	.99	1.01
Hem-Fir	.92	1.08
Spruce-Pine-Fir (South)		
Engelmann Spruce	.80	1.25
Lodgepole Pine	.92	1.08
Western Woods		
Ponderosa Pine/Sugar Pine	.89	1.12
Idaho White Pine	.84	1.19
Alpine Fir	.75	1.33
Mountain Hemlock	.98	1.02
Western Cedars	.75	1.33

[1] k values shown are for wood with 12% moisture content. For other moisture contents, there is a change in k of approximately .01 for each 1% moisture content difference—an increase in k for an increase in moisture content and a decrease in k for a decrease in moisture content.

Used courtesy of Western Wood Products Assn.

4.2.0 Southern Pine

This wood species consists of four principal types: loblolly, short leaf, long leaf, and slash from areas in the United States south of the Mason-Dixon Line and west of the Great Plains. Minor species include Virginia pine, pond pine, sand pine, spruce pine, pitch pine, and table mountain pine. Southern pine is noted for its great strength and stiffness, having the highest density of all commonly used wood products.

4.2.1 Standard Sizes—Southern Pine

STANDARD SIZES OF SOUTHERN PINE

Based on SPIB Grading Rules

	Thickness					Width				
	Nominal	Dressed				Nominal	Dressed			
		Dry		Green			Dry		Green	
	inches	inches	mm	inches	mm	inches	inches	mm	inches	mm
Dimension Lumber dressed, S4S[1]	2	1-1/2	38			2	1-1/2	38		
	2-1/2	2	51	2-1/16	52	3	2-1/2	64	2-9/16	65
	3	2-1/2	64	2-9/16	65	4	3-1/2	89	3-9/16	90
	3-1/2	3	76	3-1/16	78	5	4-1/2	114	4-5/8	117
	4	3-1/2	89	3-9/16	90	6	5-1/2	140	5-5/8	143
						8	7-1/4	184	7-1/2	190
						10	9-1/4	235	9-1/2	241
						12	11-1/4	286	11-1/2	292
						14	13-1/4	337	13-1/2	343
						16	15-1/4	387	15-1/2	394
						18	17-1/4	438	17-1/2	444
						20	19-1/4	489	19-1/2	495
Timbers dressed, S4S[1]	5" & thicker	1/2" off nominal		1/2" off nominal		5" & wider	1/2" off nominal		1/2" off nominal	

	Nominal inches	Dressed inches	Dressed mm	Nominal inches	Dressed inches	Dressed mm
Boards dressed, S4S, dry	1	3/4[2]	19	2	1-1/2	38
	1-1/4	1	25	3	2-1/2	64
	1-1/2	1-1/4	32	4	3-1/2	89
				5	4-1/2	114
				6	5-1/2	140
				7	6-1/2	165
				8	7-1/4	184
				9	8-1/4	210
				10	9-1/4	235
				11	10-1/4	260
				12	11-1/4	286
				over 12	3/4" off nominal	19 mm off nominal

	Nominal inches	Dressed inches	Dressed mm	Nominal inches	Dressed inches	Dressed mm
Finish dressed, dry	3/8	5/16	8	2	1-1/2	38
	1/2	7/16	11	3	2-1/2	64
	5/8	9/16	14	4	3-1/2	89
	3/4	5/8	16	5	4-1/2	114
	1	3/4	19	6	5-1/2	140
	1-1/4	1	25	7	6-1/2	165
	1-1/2	1-1/4	32	8	7-1/4	184
	1-3/4	1-3/8	35	9	8-1/4	210
	2	1-1/2	38	10	9-1/4	235
	2-1/2	2	51	11	10-1/4	260
	3	2-1/2	64	12	11-1/4	286
	3-1/2	3	76	14	13-1/4	337
	4	3-1/2	89	16	15-1/4	387

	Nominal inches	Dressed inches	Dressed mm	Nominal inches	Dressed inches	Dressed mm
Radius Edge Decking dressed, S4S, dry	1-1/4	1	25	4	3-1/2	89
				5	4-1/2	114
				6	5-1/2	140

(1) Dimension Lumber 2" thick and less than 14" wide is required to be dry with a moisture content of 19% or less. Heavy Dimension Lumber (2x14 and wider, 2-1/2" thick by all widths, and 3x3 and larger) and Timbers are not required to be dry unless specified. Thicknesses apply to their corresponding widths as squares and wider, except a thickness of 1-9/16" applies to nominal 2" in widths of 14" and wider if dressed green. (In 2" Dimension, widths over 12" are not customary stock sizes, so 2x14 and wider sizes are usually produced only on special order.)

(2) Boards less than the minimum dressed thickness for 1" nominal but which are 5/8" or greater thickness dry may be regarded as American Standard Lumber, but such Boards shall be marked to show the size and condition of seasoning at the time of dressing. They shall also be distinguished from 1" Boards on invoices and certificates.

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4.2.2 Southern Pine Inspection Bureau Grading Rules

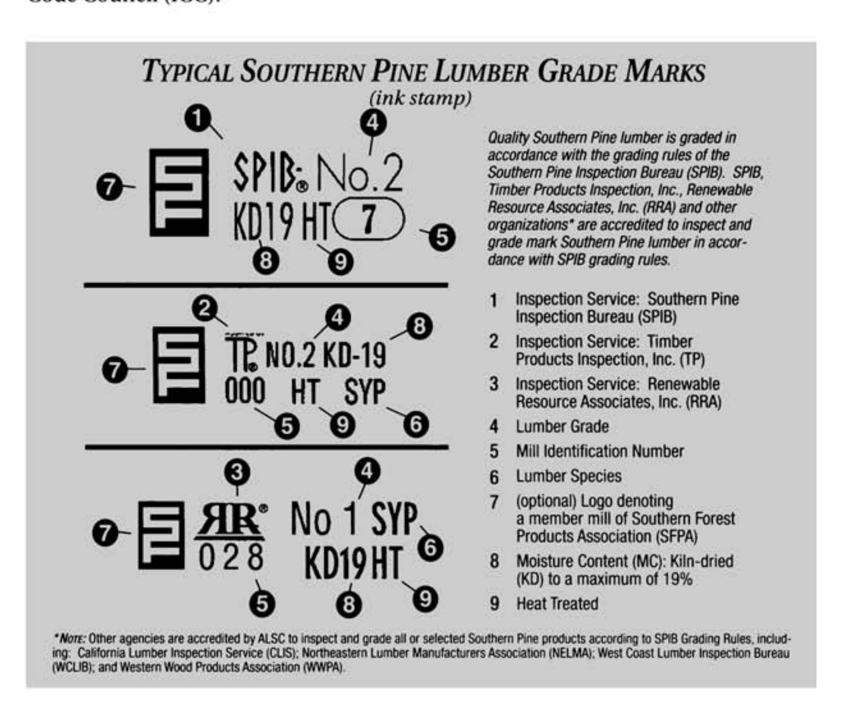
GRADE AND QUALITY MARKS

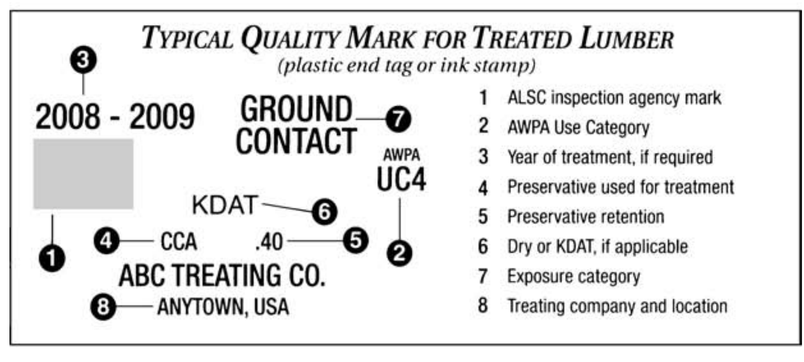
To protect the buyer and consumer, the industry has developed a system requiring ink-stamped grade marking of each piece of lumber under adequate quality control measures. This assures delivery of the grade specified for its intended use. Lumber grading and marking is monitored and inspected by agencies accredited by the American Lumber Standard Committee (ALSC). A valid agency grade mark on Southern Pine lumber indicates the product meets structural and appearance requirements established for that grade.

In addition, all treated Southern Pine should be identified with an inspection agency quality mark (either plastic end tag or ink stamp) conforming to building code standards (see Code Acceptance and Standards, page 11). For the quality mark to be valid after treatment, the lumber must adhere to the grade requirements and the moisture content of the grade represented by the mark.

SPECIFY QUALITY

It is recommended that the buyer specify pressure-treated wood bearing ink-stamped quality marks and/or plastic end tags denoting the material was produced under supervision of an independent inspection agency accredited by the ALSC. Use of such marks by the producer provides assurance that the preservative retention and penetration complies with AWPA and/or Building Code specifications, and that the preservative used is EPA approved and treated in compliance with federal law. Use of treated wood that does not bear an approved agency quality mark will not meet requirements of the International Code Council (ICC).





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4.2.2 Southern Pine Inspection Bureau Grading Rules (Continued)

LUMBER SPECIFICATION EXAMPLES[1] *Based on SPIB Grading Rules and AWPA Standards*

Use	Product Classification	Size inches – nominal	Length feet	Species	Grade	Moisture Content	Surface Texture	AWPA Use Category	Treatment & Retention
Sill Plate[2]	Dimension Lbr or Structural Light Framing	2 x 4	x 12, 14, 16	SP	No.3	KD19	S4S	UC2 (Above Ground, Interior Damp)	SBX .17 pcf KDAT
Sill Beam[2]	Timbers	6 x 8	x 16	SP	No.2		S4S	UC2 (Above Ground, Interior Damp)	ACQ .25 pcf or CA-B .10 pcf
Solid-Sawn Stud	Dimension Lbr or Studs	2 x 4	x 92-5/8″ PET	SP	Stud	KD19	S4S	UC1 (Above Ground, Interior Dry)	SBX .17 pcf KDAT
Finger-Jointed Stud	Glued Lumber (Stud Use Only) HRA	2 x 4	x 104-5/8″ PET	SP	No.2	KD19	S4S		
PWF[2] Stud	Dimension Lbr or Structural Joists & Planks	2 x 6	x 10	SP	No.2	KD19	S4S	UC4B (Ground Contact, Critical)	CCA .60 pcf KDAT
Roof Rafter	Dimension Lbr or Structural Joists & Planks	2 x 6	x 8 - 20	SP	MSR 2400f-2.0E	KD19	S4S	UC1 (Above Ground, Interior Dry)	SBX .17 pcf KDAT
Floor Joist	Dimension Lbr or Structural Joists & Planks	2 x 10	x 6 - 16	SP	MEL M-29	KD19	S4S	UC1 (Above Ground, Interior Dry)	SBX .28 pcf KDAT (Formosan Termites)
Outdoor Deck Joist[3]	Dimension Lbr or Structural Joists & Planks	2 x 8	x 12	SP	No.2		S4S	UC3B (Above Ground, Exterior)	ACQ .25 pcf or CA-B .10pcf
Outdoor Deck Decking[3]	Radius Edge Decking	5/4 x 6	x 12	SP	Premium R.E.D.		S4S Eased Edges	UC3B (Above Ground, Exterior)	ACQ .15 pcf or CA-B .08 pcf Water Repellant)
Post-Frame Building Post[2]	Timbers	6 x 6	x 16	SP	No.1	S-GRN (25%)	S4S	UC4B (Ground Contact, Critical)	ACQ .50 pcf or CA-B .25 pcf
Highway Guardrail Post[2]	Timbers	6 x 8	x 16	SP	No.2		S4S	UC4B (Ground Contact, Critical)	CCA .50 pcf
Fence Post[2]	Dimension Lbr or Structural Light Framing	4 x 4	x 8	SP	No.2		S4S	UC4A (Ground Contact, Non-critical)	ACQ .40 pcf or CA-B .21 pcf
Heavy Timber Decking	Decking	3 x 6	R/L	SP	Select Decking	KD15	S2S&CM -EV1S	UC1 (Above Ground, Interior Dry)	SBX .17 pcf KDAT
Marine Bulkhead[2]	Heavy Dimension Lbr or Structural Joists & Planks	3 x 6	x 12	SP	No.1 Seawall		S4S	UC5C (Salt Water, Gulf Coast)	CCA 2.5 pcf
Flooring	Flooring	1 x 3-1/8 (Net Dry)	x 8, 10, 12	SP	D	KD (12%)	S2S&SM (Flat Grain)		
Porch Flooring[3]	Flooring	1 x 4	x 12	SP	D	Dry (15%)	S2S&SM	UC3B (Above Ground, Exterior)	ACQ .25 pcf KDAT or CA-B .10 pcf KDAT
Siding	Drop Siding	1 x 6	x 10	SP	No.2	KD15	Pattern #116	UC3A (Above Ground, Exterior, Coated)	ACQ .25 pcf KDAT or CA-B .10 pcf KDAT
Fascia	Finish	1 x 6	x 12	SP	C&Btr	KD 15	S4S	UC3A (Above Ground, Exterior, Coated)	ACQ .25 pcf KDAT or CA-B .10 pcf KDAT
Ceiling	Ceiling and Partition	5/8 x 4	x 8	SP	D	KD (12%)	S2S&CM -EV1S		
Paneling	Paneling	1 x 5-1/8 (Net Dry)	x 10	SP	C&Btr	KD (12%)	Pattern #SPP 62	UCFA (Above Ground, Interior)	Fire Retartant for Fire Protection Flame Spread Class A
Trim	Moulding	1 x 4	x 8	SP	D	KD (12%)	S4S		

[1]**Abbreviations:** ACQ – Alkaline Copper Quat; AWPA – American Wood Protection Association; C&Btr – grade C and better; CA-B – Copper Azole Type-B; CCA – Chromated Copper Arsenate; DNS – Dense; HRA – Heat Resistant Adhesive; KD – Kiln-Dried; KDAT – Kiln-Dried After Treatment; Lbr – Lumber; MEL – Machine Evaluated Lumber; MSR – Machine Stress Rated; PET – Precision End Trim; PWF – Permanent Wood Foundation; R/L – Random Lengths; R.E.D. – Radius Edge Decking; S-GRN – surface green; S1S2E – surfaced one side and two edges; S2S&CM-EV1S – surfaced two sides and center matched with edge V on one side; S2S&SM – surfaced two sides and standard matched; S4S – surfaced four sides; SBX – Inorganic Boron; SP – Southern Pine (could also be SYP for Southern Yellow Pine); SPIB – Southern Pine Inspection Bureau; SPP – Standard Patterns of Paneling; UC – Use Category; [2]Preservative treatment code required; [3]Preservative treatment recommended

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4.2.3 Southern Pine Service Conditions

AWPA Use Category System

The AWPA Use Category System (UCS) establishes major exposure conditions that wood products are subjected to in service. The UCS helps users identify the exposure condition for specific products and end-use environments (Table 13), and then specify the acceptable preservatives and retention levels for that application.

Specify the following items (see example to right):

- ***Step 1*** *– Use Category (Table 13)*
- ***Step 2*** *– General Commodity Classification and Specification Section in the AWPA Book of Standards*
- ***Step 3*** *– Specific Commodity Classification*
- ***Step 4*** *– Species, Preservatives, and Retention Levels*
- ***Step 5*** *– Special Requirements (such as pre- or post-treatment preparations, including conditioning and drying such as Kiln Dried After Treatment, KDAT)*

For more complete treated specification information, refer to *Pressure-Treated Southern Pine* or *AWPA Book of Standards*.

Specification Example

Treated sawn-lumber joists supporting an outdoor deck

Step 1 – Use Category: **UC3B**
(from Table 13: Exterior Construction, Above Ground, Uncoated or poor water run-off Service Conditions. Typical Applications include deck joists.)

Step 2 – General Commodity Classification and Specification section in the *AWPA Book of Standards*
Sawn Products – A

Step 3 – Specific Commodity Classification: **Joists**
(Commodity – Joists, Use – Building Construction, Exposure – Above Ground, Exterior)

Step 4 – Species: **Southern Pine**
Preservatives and retention levels: **Alkaline Copper Quat (ACQ), to .25 pcf** *or* **Copper Azole (CA-B) to .10 pcf**
(Above Ground, Exterior)

Step 5 – Special Requirements: **None**

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4.2.3 Southern Pine Service Conditions (Continued)

Table 13 Service Conditions for Use Category Designations

Use Category	Service Conditions	Use Environment	Common Agents of Deterioration	Typical Applications
UC1	Interior construction Above ground Dry	Continuously protected from weather or other sources of moisture	Insects only	Interior construction and furnishings
UC2	Interior construction Above ground Damp	Protected from weather, but may be subject to sources of moisture	Decay fungi and insects	Interior construction
UC3A	Exterior construction Above ground Coated and rapid water run-off	Exposed to all weather cycles, not exposed to prolonged wetting	Decay fungi and insects	Coated millwork, siding and trim
UC3B	Exterior construction Above ground Uncoated or poor water run-off	Exposed to all weather cycles, including prolonged wetting	Decay fungi and insects	Decking, deck joists, railings, fence pickets, uncoated millwork
UC4A	Ground contact or fresh water Non-critical components	Exposed to all weather cycles, normal exposure conditions	Decay fungi and insects	Fence, deck, and guardrail posts, crossties and utility poles (low decay areas)
UC4B	Ground contact or fresh water Critical components or difficult replacement	Exposed to all weather cycles, high decay potential, includes salt water splash	Decay fungi and insects with increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties and utility poles (high decay areas)
UC4C	Ground contact or fresh water Critical structural components	Exposed to all weather cycles, severe environments, extreme decay potential	Decay fungi and insects with extreme potential for biodeterioration	Land and fresh water piling, foundation piling, crossties and utility poles (severe decay areas)
UC5A	Salt or brackish water and adjacent mud zone Northern waters	Continuous marine exposure (salt water)	Salt water organisms	Piling, bulkheads, bracing
UC5B	Salt or brackish water and adjacent mud zone NJ to GA, south of SanFran	Continuous marine exposure (salt water)	Salt water organisms, including creosote tolerant, *Limnoria tripunctata*	Piling, bulkheads, bracing
UC5C	Salt or brackish water and adjacent mud zone South of GA, Gulf Coast, Hawaii, and Puerto Rico	Continuous marine exposure (salt water)	Salt water organisms, including *Martesia, Sphaeroma*	Piling, bulkheads, bracing
UCFA	Fire protection as required by codes Above ground Interior construction	Continuously protected from weather or other sources of moisture	Fire	Roof sheathing, roof trusses, studs, joists, paneling
UCFB	Fire protection as required by codes Above ground Exterior construction	Subject to wetting	Fire	Vertical exterior walls, inclined roof surfaces or other construction which allows water to quickly drain

NOTE: Table 13 copyright AWPA, *Book of Standards, 2008 Edition,* Section 2, Service Conditions for Use Category Designations.

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4.2.4 Southern Pine Products and Sizes

SOUTHERN PINE PRODUCT AND GRADE DESCRIPTIONS

Based on SPIB Grading Rules
See www.southernpine.com for Product Locator

Product	Grade	Grade Characteristics and Typical Uses
Dimension Lumber: 2″ to 4″ thick, 2″ and wider *See Table 1 for design values*		
	*Dense Select Structural Select Structural *Select Structural NonDense	High quality, limited in characteristics that affect strength or stiffness. Recommended for uses where high strength, stiffness and good appearance are desired.
	*No.1 Dense No.1 *No.1 NonDense	Recommended for construction where high strength, stiffness and good appearance are desired.
	*No.2 Dense No.2 *No.2 NonDense	Recommended for most general construction uses where moderately high design values are required. Allows well-spaced knots of any quality.
	No.3	Recommended for general construction purposes where appearance is not a controlling factor. Many pieces included in this grade would qualify as No.2 except for a single limiting characteristic.
	Stud	Suitable for stud uses including use in load-bearing walls. Composite of No.3 strength and No.1 edge characteristics for a better nailing surface.
	*Construction (2″ to 4″ wide only)	Recommended for general framing purposes. Good appearance, but graded primarily for strength and serviceability.
	*Standard (2″ to 4″ wide only)	Recommended for same purposes as Construction grade. Characteristics are limited to provide good strength and excellent serviceability.
	*Utility (2″ to 4″ wide only)	Recommended where a combination of economical construction and good strength is desired. Used for such purposes as studding, blocking, plates, bracing and rafters.
	Design values are not assigned Economy	Usable lengths suitable for bracing, blocking, bulkheading and other general utility purposes where strength and appearance are not a consideration.

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4.2.4 Southern Pine Products and Sizes (Continued)

Prime Dimension: 2″ to 4″ thick, 2″ to 12″ wide *See Table 1 for design values*	
No.1 Prime	Recommended where appearance and strength are a consideration. Grade based on No.1 Dimension Lumber except wane and other characteristics that affect appearance are limited.
No.2 Prime	Recommended where appearance and strength are a consideration. Grade based on No.2 Dimension Lumber except wane and other characteristics that affect appearance are limited.
***Timbers: 5″ x 5″ and larger** *See Table 2 for design values*	
Dense Select Structural Select Structural	Recommended where high strength, stiffness and good appearance are desired.
No.1 Dense No.1	Recommended for general construction uses. Similar in appearance to No.1 Dimension Lumber.
No.2 Dense No.2	Recommended for general construction uses. Similar in appearance to No.2 Dimension Lumber.
Design values are not assigned No.3	Non-stress rated, but economical for general utility purposes such as bracing, blocking, bulkheading, etc.

* Most mills do not manufacture all products and make all grade separations. Those products and grades not manufactured by most mills are noted with an asterisk.

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4.2.4 Southern Pine Products and Sizes (Continued)

SOUTHERN PINE PRODUCT AND GRADE DESCRIPTIONS (CONT'D)

Based on SPIB Grading Rules
See www.southernpine.com for Product Locator

Product	Grade	Grade Characteristics and Typical Uses
***Mechanically Graded Lumber – Machine Stress Rated (MSR) Lumber: 2″ and less in thickness, 2″ and wider** *See Table 3 or SPIB Grading Rules for design values*		
	1650f–1.5E thru 3000f–2.4E	Machine Stress Rated (MSR) lumber is evaluated by mechanical stress rating equipment. MSR lumber is distinguished from visually stress graded lumber in that each piece is non-destructively tested. MSR lumber is also required to meet certain visual grading requirements.
***Mechanically Graded Lumber – Machine Evaluated Lumber (MEL): 2″ and less in thickness, 2″ and wider** *See Table 3 or SPIB Grading Rules for design values*		
	M–5 thru M–31	Well-manufactured material evaluated by calibrated mechanical grading equipment which measures certain properties and sorts the lumber into various strength classifications. Machine Evaluated Lumber is also required to meet certain visual requirements.
***E-rated Structural Laminations: 2″ and less in thickness, 2″ and wider** *Design Values by qualification*		
	E–grades	Suitable for use as individual laminations for structural glued laminated timbers. This lumber has been non-destructively evaluated by an American Lumber Standard Committee approved machine.
***Glued Lumber: 4" and less in thickness, widths vary by product** *See Table 1 for design values*		
	See Dimension Lumber Grades	End-glued, face-glued, and edge-glued Southern Pine in glued assemblies, including stress-rated grades of finger-jointed 2" Dimension Lumber.
***Scaffold Plank: 2″ and 3″ thick, 8″ and wider** *See Table 4 for design values*		
	Dense Industrial 72 Scaffold Plank Dense Industrial 65 Scaffold Plank	All Scaffold Plank design values are calculated using ASTM Standards D245 and D2555. These values are modified using procedures shown in "Calculating Apparent Reliability of Wood Scaffold Planks," as published by the Journal on Structural Safety, 2 (1984) 47-57, and updated in 1993.
	MSR Scaffold Plank: 2400f–2.0E MSR Scaffold Plank: 2200f–1.8E	Dressed to standard dry size prior to machine stress rating, and visually graded to assure that characteristics affecting strength are no more serious than the limiting characteristics for each grade. MSR Scaffold Plank is available 2″-thick only.
***Stadium Grade: 2″ thick, 4″ to 12″ wide** *See Table 1 for design values*		
	No.1 Dense Stadium Grade No.1 Stadium Grade	For outdoor seating. Free of pitch pockets, pitch streaks and medium pitch on one wide face, but otherwise conforms to No.1 Dense or No.1 Dimension Lumber.
***Seawall Grades: 2″ to 4″ thick, 6″ to 14″ wide** *See Table 1 for design values*		
	Any grade of Dimension Lumber	One wide face and both adjacent narrow faces must be free of pith and/or heartwood. Application of the product requires pressure treatment by an approved treating process and preservative for marine usage.

* Most mills do not manufacture all products and make all grade separations. Those products and grades not manufactured by most mills are noted with an asterisk.

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4.2.4 Southern Pine Products and Sizes (Continued)

SOUTHERN PINE PRODUCT AND GRADE DESCRIPTIONS (CONT'D)

Based on SPIB Grading Rules
See www.southernpine.com for Product Locator

Product	Grade	Grade Characteristics and Typical Uses
***Marine Grades: 1″ to 20″ thick, 2″ to 20″ wide** *See Tables 1 and 2 for design values*		
	Any grade of Dimension Lumber or Timbers	All four longitudinal faces must be free of pith and/or heartwood. Application of the product requires pressure treatment by an approved treating process and preservative for marine usage.
***Decking, Heavy Roofing and Heavy Shiplap: 2″ to 4″ thick, 2″and wider** *See SPIB Grading Rules for design values*		
	Dense Standard Decking	A superior decking grade, suitable for plank floor where face serves as finish floor. Has a better appearance than No.1 Dense Dimension Lumber because of additional restrictions on firm red heart, pith, knots and wane.
	Dense Select Decking Select Decking	An excellent decking grade that can be used face side down for roof decking or face side up for floor decking.
	Dense Commercial Decking Commercial Decking	An economical roof decking which conforms to No.2 Dimension Lumber characteristics.
Boards: 1″ to 1-1/2″ thick, 2″ and wider *See Table 1 for design values*		
	Industrial 55	Graded as per No.1 Dimension Lumber.
	Industrial 45	Graded as per No.2 Dimension Lumber.
	Industrial 26	Graded as per No.3 Dimension Lumber.
Design values are not assigned		
	No.1	High quality with good appearance characteristics. Generally sound and tight-knotted. Largest hole permitted is 1/16″. Superior product suitable for a wide range of uses including shelving, boxing, crating, and form lumber.
	No.2	Good-quality sheathing, fencing, shelving and other general purpose uses.
	No.3	Good, serviceable sheathing; usable for many economical applications without waste.
	No.4	Admits pieces below a No.3 grade which can be used without waste, or which contain less than 25% waste by cutting.
***Industrial Lumber: 2″ and thicker, 2″ and wider** *See SPIB Special Product Rules for design values*		
	Industrial 86	Appearance is same as B&B Finish for thicknesses of 4″ and less and widths 12″ and less. Larger sizes conform to Dense Structural 86 Structural Lumber except for dense grain requirement.
	Industrial 72	Appearance is same as C Finish for thicknesses of 4″ and less and widths 12″ and less. Larger sizes conform to Dense Structural 72 Structural Lumber except for dense grain requirement.
	Industrial 65	Appearance is same as D Finish for thicknesses of 4″ and less and widths 12″ and less. Larger sizes conform to Dense Structural 65 Structural Lumber except for dense grain requirement.

* Most mills do not manufacture all products and make all grade separations. Those products and grades not manufactured by most mills are noted with an asterisk.

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4.2.4 Southern Pine Products and Sizes (Continued)

SOUTHERN PINE PRODUCT AND GRADE DESCRIPTIONS (CONT'D)

Based on SPIB Grading Rules
See www.southernpine.com for Product Locator

Product	Grade	Grade Characteristics and Typical Uses
***Structural Lumber: 2″ and thicker, 2″ and wider** *See SPIB Special Product Rules for design values*		
	Dense Structural 86 Dense Structural 72 Dense Structural 65	Premier structural grades. Provides good appearance with some of the highest design values available in any softwood species.
Radius Edge Decking: 1-1/4″ thick, 4″ to 6″ wide *Maximum recommended support spacing is 24″ on center (16″ on center for Imported Southern Pine)*		
	Premium	High-quality product, recommended where smallest knots are desired and appearance is of utmost importance. Excellent for painting or staining.
	Standard	Slightly less restrictive than premium grade. A very good product to use where a more rustic appearance is desired. Excellent for painting or staining.
Finish: 3/8″ to 4″ thick, 2″ and wider *Design values are not assigned*		
	*B&B	Highest recognized grade of Finish. Generally clear, although a limited number of pin knots are permitted. Finest quality for natural or stain finish.
	C	Excellent for painting or natural finish where requirements are less exacting. Reasonably clear, but permits limited number of surface checks and small tight knots.
	C&Btr	Combination of B&B and C grades; satisfies requirements for high-quality finish.
	D	Economical, serviceable grade for natural or painted finish.
Flooring, Drop Siding, Paneling, Ceiling and Partition, OG Batts, Bevel Siding, Miscellaneous Millwork *Design values are not assigned*		
	*B&B, C C&Btr, D	See Finish grades for face side; reverse side wane limitations are lower.
	No.1	No.1 Drop Siding is graded as No.1 Boards; No.1 Flooring and Paneling not provided under SPIB Grading Rules as a separate grade, but if specified, will be designated and graded as D.
	No.2	Graded as No.2 Boards. High utility value where appearance is not a factor.
	No.3	Suitable for economical use as sheathing or lathing.
Moulding *Design values are not assigned*		
	B&B, C C&Btr, D	Recommended for moulding and millwork applications.

*Most mills do not manufacture all products and make all grade separations. Those products and grades not manufactured by most mills are noted with an asterisk.

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4.2.5 Southern Pine Design Values—Span Tables

SOUTHERN PINE SPAN TABLES – ALLOWABLE STRESS DESIGN

Maximum spans given in feet and inches
Inside to inside of bearings

Tables 5 thru 11 are abbreviated span tables for the most commonly available grades of Southern Pine lumber. For other grades, loading conditions and spacings, refer to the SPC publication *Maximum Spans for Southern Pine Joists and Rafters.*

These spans are based on *AF&PA'S Span Tables for Joists and Rafters*, and the *SPIB Standard Grading Rules for Southern Pine Lumber.* Except for Table 8, they are intended for use in covered structures or where the moisture content in use does not exceed 19 percent for an extended period of time.

Table 5 Floor Joists

Design Criteria: Deflection – limited to span in inches divided by 360 (live load only).
Strength – based on 30, 40, or 50 pounds per square foot (psf) live load, plus 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 6			2 x 8			2 x 10			2 x 12		
Grade	Live Load	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	30 psf	12 – 0	10 – 11	9 – 7	15 – 10	14 – 5	12 – 7	20 – 3	18 – 5	16 – 1	24 – 8	22 – 5	19 – 6
	40 psf	10 – 11	9 – 11	8 – 8	14 – 5	13 – 1	11 – 5	18 – 5	16 – 9	14 – 7	22 – 5	20 – 4	17 – 5
	50 psf	10 – 2	9 – 3	8 – 1	13 – 5	12 – 2	10 – 8	17 – 1	15 – 6	13 – 4	20 – 9	18 – 10	15 – 11
No.2	30 psf	11 – 10	10 – 9	9 – 4	15 – 7	14 – 2	12 – 4	19 – 10	18 – 0	14 – 8	24 – 2	21 – 1	17 – 2
	40 psf	10 – 9	9 – 9	8 – 6	14 – 2	12 – 10	11 – 0	18 – 0	16 – 1	13 – 1	21 – 9	18 – 10	15 – 5
	50 psf	9 – 11	9 – 1	7 – 9	13 – 1	11 – 11	10 – 0	16 – 9	14 – 8	12 – 0	19 – 10	17 – 2	14 – 0
No.3	30 psf	10 – 5	9 – 0	7 – 4	13 – 3	11 – 6	9 – 5	15 – 8	13 – 7	11 – 1	18 – 8	16 – 2	13 – 2
	40 psf	9 – 4	8 – 1	6 – 7	11 – 11	10 – 3	8 – 5	14 – 0	12 – 2	9 – 11	16 – 8	14 – 6	11 – 10
	50 psf	8 – 6	7 – 4	6 – 0	10 – 10	9 – 5	7 – 8	12 – 10	11 – 1	9 – 1	15 – 3	13 – 2	10 – 9

Table 6 Ceiling Joists – Drywall Ceiling

Design Criteria: Deflection – limited to span in inches divided by 240 (live load only).
Strength – based on 10 or 20 pounds per square foot (psf) live load, plus 5 or 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 4			2 x 6			2 x 8			2 x 10		
Grade	Live Load	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	10 psf	12 – 8	11 – 6	10 – 0	19 – 11	18 – 1	15 – 9	26 – 0*	23 – 10	20 – 10	26 – 0*	26 – 0*	26 – 0*
	20 psf	10 – 0	9 – 1	8 – 0	15 – 9	14 – 4	12 – 6	20 – 10	18 – 11	15 – 10	26 – 0*	23 – 1	18 – 10
No.2	10 psf	12 – 5	11 – 3	9 – 10	19 – 6	17 – 8	15 – 6	25 – 8	23 – 4	20 – 1	26 – 0*	26 – 0*	23 – 11
	20 psf	9 – 10	8 – 11	7 – 8	15 – 6	13 – 6	11 – 0	20 – 1	17 – 5	14 – 2	23 – 11	20 – 9	16 – 11
No.3	10 psf	11 – 6	10 – 0	8 – 2	17 – 0	14 – 9	12 – 0	21 – 8	18 – 9	15 – 4	25 – 7	22 – 2	18 – 1
	20 psf	8 – 2	7 – 1	5 – 9	12 – 0	10 – 5	8 – 6	15 – 4	13 – 3	10 – 10	18 – 1	15 – 8	12 – 10

Table 7 Floor Joists – Heavy Live Loads

Design Criteria: Deflection – limited to span in inches divided by 360 (live load only).
Strength – based on 75, 100, 125 or 150 pounds per square foot (psf) live load, plus 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 6			2 x 8			2 x 10			2 x 12		
Grade	Live Load	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	75 psf	8 – 10	8 – 1	7 – 1	11 – 8	10 – 8	9 – 3	14 – 11	13 – 7	11 – 2	18 – 2	16 – 4	13 – 4
	100 psf	8 – 1	7 – 4	6 – 5	10 – 8	9 – 8	8 – 3	13 – 7	12 – 1	9 – 10	16 – 6	14 – 5	11 – 9
	125 psf	7 – 6	6 – 10	5 – 11	9 – 10	9 – 0	7 – 6	12 – 7	10 – 11	8 – 11	15 – 0	13 – 0	10 – 7
	150 psf	7 – 1	6 – 5	5 – 6	9 – 3	8 – 5	6 – 10	11 – 7	10 – 0	8 – 2	13 – 9	11 – 11	9 – 9
No.2	75 psf	8 – 8	7 – 11	6 – 6	11 – 6	10 – 4	8 – 5	14 – 3	12 – 4	10 – 1	16 – 8	14 – 5	11 – 10
	100 psf	7 – 11	7 – 0	5 – 9	10 – 5	9 – 1	7 – 5	12 – 6	10 – 10	8 – 10	14 – 8	12 – 8	10 – 4
	125 psf	7 – 4	6 – 4	5 – 2	9 – 6	8 – 2	6 – 8	11 – 4	9 – 9	8 – 0	13 – 3	11 – 6	9 – 4
	150 psf	6 – 9	5 – 10	4 – 9	8 – 8	7 – 6	6 – 2	10 – 4	9 – 0	7 – 4	12 – 2	10 – 6	8 – 7
No.3	75 psf	7 – 2	6 – 2	5 – 1	9 – 1	7 – 11	6 – 5	10 – 9	9 – 4	7 – 7	12 – 10	11 – 1	9 – 1
	100 psf	6 – 3	5 – 5	4 – 5	8 – 0	6 – 11	5 – 8	9 – 5	8 – 2	6 – 8	11 – 3	9 – 9	8 – 0
	125 psf	5 – 8	4 – 11	4 – 0	7 – 3	6 – 3	5 – 1	8 – 6	7 – 5	6 – 0	10 – 2	8 – 10	7 – 2
	150 psf	5 – 3	4 – 6	3 – 8	6 – 8	5 – 9	4 – 8	7 – 10	6 – 9	5 – 7	9 – 4	8 – 1	6 – 7

* The listed maximum span has been limited to 26′ - 0″ based on material availability. Check sources of supply for lumber longer than 20′.

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4.2.5 Southern Pine Design Values—Span Tables (Continued)

SOUTHERN PINE SPAN TABLES – ALLOWABLE STRESS DESIGN

Maximum spans given in feet and inches
Inside to inside of bearings

Table 8 Wet-Service Floor Joists

Design Criteria: Deflection – limited to span in inches divided by 360 (live load only).
Strength – based on 40, 60, or 100 pounds per square foot (psf) live load, plus 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 6			2 x 8			2 x 10			2 x 12		
Grade	Live Load	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	40 psf	10 – 7	9 – 7	8 – 5	13 – 11	12 – 8	11 – 1	17 – 9	16 – 2	13 – 6	21 – 7	19 – 8	16 – 1
	60 psf	9 – 3	8 – 5	7 – 4	12 – 2	11 – 1	9 – 7	15 – 6	13 – 11	11 – 5	18 – 10	16 – 7	13 – 7
	100 psf	7 – 9	7 – 1	6 – 1	10 – 3	9 – 4	7 – 8	12 – 10	11 – 1	9 – 1	15 – 4	13 – 3	10 – 4
No.2	40 psf	10 – 4	9 – 5	7 – 10	13 – 8	12 – 5	10 – 2	17 – 5	15 – 10	13 – 1	21 – 2	18 – 10	15 – 5
	60 psf	9 – 1	8 – 1	6 – 8	11 – 11	10 – 6	8 – 7	15 – 2	13 – 7	11 – 1	18 – 5	15 – 11	13 – 0
	100 psf	7 – 6	6 – 6	5 – 3	9 – 8	8 – 4	6 – 10	12 – 6	10 – 10	8 – 10	14 – 8	12 – 8	10 – 4
No.3	40 psf	9 – 4	8 – 1	6 – 7	11 – 11	10 – 3	8 – 5	14 – 0	12 – 2	9 – 11	16 – 8	14 – 6	11 – 10
	60 psf	7 – 11	6 – 10	5 – 7	10 – 0	8 – 8	7 – 1	11 – 10	10 – 3	8 – 5	14 – 1	12 – 3	10 – 0
	100 psf	6 – 3	5 – 5	4 – 5	8 – 0	6 – 11	5 – 8	9 – 5	8 – 2	6 – 8	11 – 3	9 – 9	8 – 0

Table 9 Rafters – Drywall or No Finished Ceiling – Construction Load (C_D = 1.25)[1]

Design Criteria: Deflection – limited to span in inches divided by 240 or 180 (live load only).
Strength – based on 20 pounds per square foot (psf) live load, plus 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 6			2 x 8			2 x 10			2 x 12		
Grade	Deflection	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	240	15 – 9	14 – 4	12 – 6	20 – 10	18 – 11	16 – 6	26 – 0*	24 – 1	21 – 1	26 – 0*	26 – 0*	25 – 2
	180	17 – 4	15 – 9	13 – 9	22 – 11	20 – 10	17 – 9	26 – 0*	25 – 10	21 – 1	26 – 0*	26 – 0*	25 – 2
No.2	240	15 – 6	14 – 1	12 – 3	20 – 5	18 – 6	15 – 10	26 – 0	23 – 2	18 – 11	26 – 0*	26 – 0*	22 – 2
	180	17 – 0	15 – 1	12 – 3	22 – 5	19 – 5	15 – 10	26 – 0*	23 – 2	18 – 11	26 – 0*	26 – 0*	22 – 2
No.3	240	13 – 6	11 – 8	9 – 6	17 – 2	14 – 10	12 – 1	20 – 3	17 – 6	14 – 4	24 – 1	20 – 11	17 – 1
	180	13 – 6	11 – 8	9 – 6	17 – 2	14 – 10	12 – 1	20 – 3	17 – 6	14 – 4	24 – 1	20 – 11	17 – 1

Table 10 Rafters – Drywall Ceiling – Snow Load (C_D = 1.15)[1]

Design Criteria: Deflection – limited to span in inches divided by 240 (live load only).
Strength – based on 30 or 40 pounds per square foot (psf) live load, plus 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 6			2 x 8			2 x 10			2 x 12		
Grade	Live Load	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	30 psf	13 – 9	12 – 6	10 – 11	18 – 2	16 – 6	14 – 5	23 – 2	21 – 1	17 – 6	26 – 0*	25 – 7	20 – 11
	40 psf	12 – 6	11 – 5	9 – 11	16 – 6	15 – 0	13 – 1	21 – 1	19 – 2	15 – 8	25 – 7	22 – 10	18 – 8
No.2	30 psf	13 – 6	12 – 3	10 – 2	17 – 10	16 – 2	13 – 2	22 – 3	19 – 3	15 – 9	26 – 0*	22 – 7	18 – 5
	40 psf	12 – 3	11 – 2	9 – 2	16 – 2	14 – 5	11 – 9	19 – 11	17 – 3	14 – 1	23 – 4	20 – 2	16 – 6
No.3	30 psf	11 – 2	9 – 8	7 – 11	14 – 3	12 – 4	10 – 1	16 – 10	14 – 7	11 – 11	20 – 0	17 – 4	14 – 2
	40 psf	10 – 0	8 – 8	7 – 1	12 – 9	11 – 0	9 – 0	15 – 1	13 – 0	10 – 8	17 – 11	15 – 6	12 – 8

Table 11 Rafters – No Finished Ceiling – Snow Load (C_D = 1.15)[1]

Design Criteria: Deflection – limited to span in inches divided by 180 (live load only).
Strength – based on 30 or 40 pounds per square foot (psf) live load, plus 10 psf dead load.

		Size (inches) and Spacing (inches on center)											
		2 x 4			2 x 6			2 x 8			2 x 10		
Grade	Live Load	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc	12″oc	16″oc	24″oc
No.1	30 psf	9 – 8	8 – 9	7 – 8	15 – 2	13 – 9	11 – 9	20 – 0	18 – 1	14 – 9	24 – 9	21 – 5	17 – 6
	40 psf	8 – 9	8 – 0	7 – 0	13 – 9	12 – 6	10 – 6	18 – 2	16 – 2	13 – 2	22 – 2	19 – 2	15 – 8
No.2	30 psf	9 – 6	8 – 7	7 – 1	14 – 5	12 – 6	10 – 2	18 – 8	16 – 2	13 – 2	22 – 3	19 – 3	15 – 9
	40 psf	8 – 7	7 – 10	6 – 4	12 – 11	11 – 2	9 – 2	16 – 8	14 – 5	11 – 9	19 – 11	17 – 3	14 – 1
No.3	30 psf	7 – 7	6 – 7	5 – 4	11 – 2	9 – 8	7 – 11	14 – 3	12 – 4	10 – 1	16 – 10	14 – 7	11 – 11
	40 psf	6 – 9	5 – 10	4 – 9	10 – 0	8 – 8	7 – 1	12 – 9	11 – 0	9 – 0	15 – 1	13 – 0	10 – 8

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4.2.5.1 Southern Pine Seasoning Requirements

SOUTHERN PINE SEASONING REQUIREMENTS*

Based on SPIB Grading Rules

Southern Pine grading rules restrict moisture content of lumber 2″ and less in thickness to a maximum of 19%. If specified as "KD," "KD19," "dry" or "air-dried" the maximum is 19%. If specified as "KD15" (kiln-dried) or "MC15" the maximum is 15%. Material identified by a certified grade mark is evidence that Southern Pine has been properly seasoned.

Moisture content restrictions apply at time of shipment, as well as time of dressing if dressed lumber is involved, and at time of delivery to buyer unless shipped exposed to the weather.

Moisture Content Limit		
Items *(Nominal thickness)*	**Kiln-Dried**	**Dry**
D and Better Grades		
1″ and 1-1/4″	Max. 12% on 90% of pieces 15% on remainder	15%
1-1/2″, 1-3/4″ and 2″	15%	18%
Over 2″, but not over 4″	15%	19%
Over 4″	18%	20%
Paneling	12%	12%
Boards[1]	19%	19%
Dimension[1, 2]	19%	19%
Decking[3]	19%	19%
Timbers[2]	20%	23%

* Lumber dressed at a moisture content within the limits of these rules is sufficiently stabilized for most uses, but limited size changes will occur from shrinkage or expansion if the moisture content is further reduced or increased after dressing. The normal shrinkage allowance is 1% reduction in size for each 4-point reduction in percentage of moisture content and same tolerance for any expansion.

(1) KD15 or MC15 may be specified if desired.

(2) Moisture content provisions must be specified for material 2-1/2″ and thicker because seasoning is not mandatory for these sizes.

(3) All thicknesses of roof decking should be specified at 15% maximum moisture content.

AMERICAN SOFTWOOD LUMBER *STANDARD*

The *American Softwood Lumber Standard PS 20*, of the U.S. Department of Commerce relates lumber size to moisture content. Separate size schedules for green and dry lumber assure that both products will approximate the same size in service. All bills and invoices are required to show actual net sizes of lumber. Strength and stiffness values for Southern Pine products in current SPIB rules have been approved by the Board of Review of the American Lumber Standard Committee. *PS 20* provides for a *National Grading Rule (NGR) for Dimension Lumber* ‡ with simplified grade names and sizes to assure uniformity, efficiency and economy in the use of dimension lumber. The *NGR* is incorporated in the *SPIB Standard Grading Rules for Southern Pine Lumber*, published by the Southern Pine Inspection Bureau.

‡ *NGR* applies to dimension lumber and excludes items such as crossarms, factory and shop lumber, finish (selects), foundation lumber, industrial clears, ladder stock, laminating stock, railroad stock, rough lumber, scaffold planks, ship decking and plank stock, stadium plank, worked lumber, and special product rules for items such as radius edge decking, and prime & merchantable dimension.

Dimension lumber sizes and grades are:

Structural Light Framing: 2″ to 4″ thick, 2″ to 4″ wide
Select Structural, No.1, No.2, No.3
Select Structural, No.1 and No.2 grades also include Dense and NonDense options.

Light Framing: 2″ to 4″ thick, 2″ to 4″ wide
Construction, Standard, Utility

Studs: 2″ to 4″ thick, 2″ and wider
Stud

Structural Joists & Planks: 2″ to 4″ thick, 5″ and wider
Select Structural, No.1, No.2, No.3
Select Structural, No.1 and No.2 grades also include Dense and NonDense options.

SOUTHERN PINE REINSPECTION AVAILABILITY

In absence of special agreement between buyer and seller, the *SPIB Standard Grading Rules for Southern Pine Lumber* provide that the purchase, sale or shipment of lumber designated by grades described in these rules must be construed as involving agreement to abide by all applicable provisions of the rules, including submission to inspection of any lumber under complaint as to size, grade or tally.

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4.2.6 Southern Pine Preservatives and Applications

Table 6: Posts, Commodity Specification B — Southern Pine Preservatives and Retentions[1]

Minimum Retention Requirements — Pounds per Cubic Foot (pcf)

End-Use Commodity	AWPA Use Category (UC) Designation	Waterborne: Copper Azole (CA)	Waterborne: Copper Quat - (ACQ, Micronized Copper)	Waterborne: Acid Copper Chromate (ACC)	Waterborne: Chromated Copper Arsenate (CCA)	Waterborne: Copper Naphthenate (CuN-W)	Oilborne: Copper-8-Quinolinolate (Cu8)	Oilborne: Copper Naphthenate (CuN)	Oilborne: Pentachlorophenol - A&C (PCP)	Creosote (CR, CR-PS, CR-S)
Round, Half Round and Quarter Round										
Highway, Fence, Guide, Sign and Sight	4A	0.21	0.40	0.50	0.40	0.11		0.055	0.40	8.0
Guardrail, Spacer Blocks	4B	0.25	0.50		0.50			0.069	0.50	10.0
Brine Storage	4B									10.0
Farm Use, Structural Members, Round	4B	0.31	0.60[2]		0.60				0.38	7.5[6]
Building Construction, Round	4B	0.31			0.60				0.45	9.0[5]
Playground Equipment										
Sawn	4A	0.21	0.40			0.11	0.02[7]			
Round	4A	0.21	0.40			0.11				
Sawn posts, see Table 5A										

Table 7: Crossties and Switchties, Commodity Specification C Southern Pine Preservatives and Retentions[1]

Minimum Retention Requirements — Pounds per Cubic Foot (pcf)

End-Use Commodity	AWPA Use Category (UC) Designation	Oilborne: Copper Naphthenate (CuN)	Oilborne: Pentachlorophenol - A&C (PCP)	Creosote (CR, CR-PS, CR-S)
Crossties and Switchties	4A-C	0.06	0.4	8.0

FOOTNOTES for Tables 6-10, see page 10

Table 8: Poles, Commodity Specification D — Southern Pine Preservatives and Retentions[1]

Minimum Retention Requirements — Pounds per Cubic Foot (pcf)

End-Use Commodity	AWPA Use Category (UC) Designation	Waterborne: Copper Azole (CA)	Waterborne: Copper Quat - (ACQ, Micronized Copper)	Waterborne: Chromated Copper Arsenate (CCA)	Oilborne: Copper Naphthenate (CuN)	Oilborne: Pentachlorophenol - A&C (PCP)	Creosote (CR, CR-PS, CR-S)
Round							
Agriculture, Utility, Low Decay	4A	0.31	0.60[3]	0.60	0.06	0.30	6.0[6]
Agric., Utility, Highway, Lighting	4B	0.31	0.60[3]	0.60	0.08	0.38	7.5[6]
Building Structural	4B	0.31		0.60		0.45	9.0[5]
Utility, Lighting, High Decay	4C		0.60[3]		0.13	0.45	9.0[6]
Glue Laminated	4A-B				0.08	0.38	7.5[5]
	4C				0.13	0.45	9.0[5]
Sawn poles, see Table 5A							

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4.2.6 Southern Pine Preservatives and Applications (Continued)

Table 9: Round Timber Piling, Commodity Specification E Southern Pine Preservatives and Retentions[1]

End-Use Commodity	AWPA Use Category (UC) Designation	Waterborne: Copper Azole (CA)	Waterborne: Copper Quat - (ACQ, Micronized Copper)	Waterborne: Chromated Copper Arsenate (CCA)	Oilborne: Copper Naphthenate (CuN)	Oilborne: Pentachlorophenol - A&C (PCP)	Creosote (CR, CR-PS, CR-S)
		Minimum Retention Requirements — Pounds per Cubic Foot (pcf)					
Land or Fresh Water Use & Foundations	4C	0.41	0.80[4]	0.80	0.10	0.60	12.0
Sawn piles, see Table 5A							

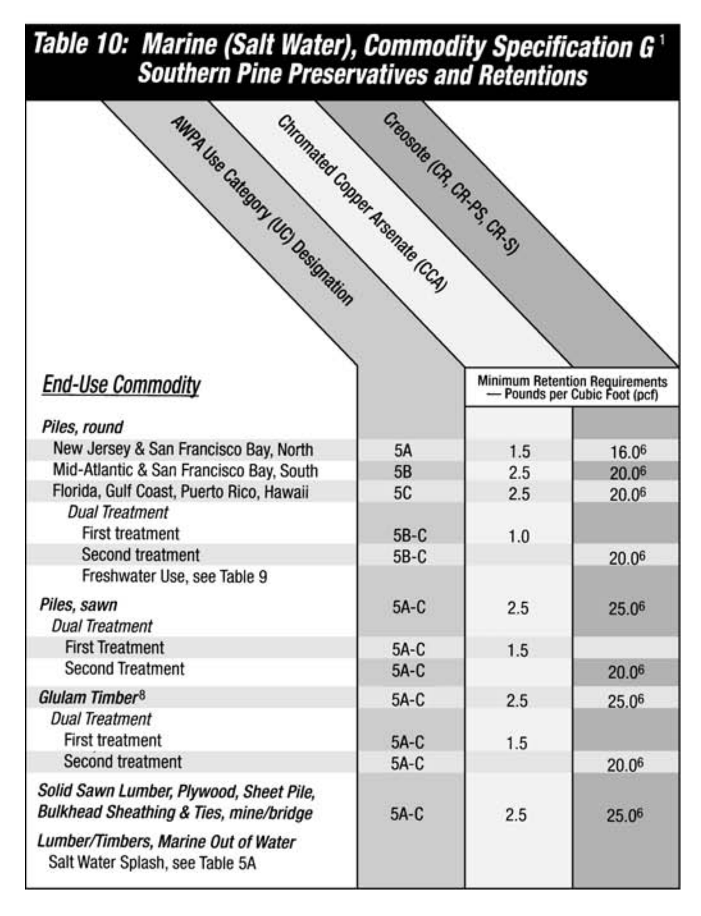


Table 10: Marine (Salt Water), Commodity Specification G[1] Southern Pine Preservatives and Retentions

End-Use Commodity	AWPA Use Category (UC) Designation	Chromated Copper Arsenate (CCA)	Creosote (CR, CR-PS, CR-S)
		Minimum Retention Requirements — Pounds per Cubic Foot (pcf)	
Piles, round			
New Jersey & San Francisco Bay, North	5A	1.5	16.0[6]
Mid-Atlantic & San Francisco Bay, South	5B	2.5	20.0[6]
Florida, Gulf Coast, Puerto Rico, Hawaii	5C	2.5	20.0[6]
Dual Treatment			
First treatment	5B-C	1.0	
Second treatment	5B-C		20.0[6]
Freshwater Use, see Table 9			
Piles, sawn	5A-C	2.5	25.0[6]
Dual Treatment			
First Treatment	5A-C	1.5	
Second Treatment	5A-C		20.0[6]
Glulam Timber[8]	5A-C	2.5	25.0[6]
Dual Treatment			
First treatment	5A-C	1.5	
Second treatment	5A-C		20.0[6]
Solid Sawn Lumber, Plywood, Sheet Pile, Bulkhead Sheathing & Ties, mine/bridge	5A-C	2.5	25.0[6]
Lumber/Timbers, Marine Out of Water Salt Water Splash, see Table 5A			

ON THE JOB SITE, KEEP IT SIMPLE AND FOLLOW THE LABEL

To avoid misuse on the job site, framing crews should follow instructions on required labels affixed to treated wood products, usually a plastic end tag or ink stamp (see page 12). Following are terms and abbreviations typically found on these labels.

Above Ground Use applications:
Continuously Protected from Liquid Water
General Use Framing Lumber
Vertical Use Fence Boards
Decking Use Only

Ground Contact Use applications:
Ground Contact (Fresh Water)

Foundation Use applications:
Permanent Wood Foundation (PWF, FDN)

Marine Grade applications:
Marine
Seawall (This Side Seaward)

Footnotes for Tables 6-10

(1) Preservatives and retentions listed in Tables 6-10 are derived from the American Wood Protection Association (AWPA) *Book of Standards, 2008 Edition.* The terms "Commodity Specification" and "Use Category (UC)," copyright AWPA. (2) ACQ-D not recommended. (3) ACQ-B and MCQ only. (4) ACQ-C only. (5) CR only. (6) CR and CR-S only. (7) For above ground use only, such as supports resting on footings above grade. (8) Glulam included in Marine Commodity Specification G per AITC 109-2007, American Institute of Timber Construction, *Standard for Preservative Treatment of Structural Glued Laminated Timber.*

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4.2.7 Wood Preservative Types

Chromated copper arsenate (CCA) was a common wood preservative used in many types of lumber beginning in the 1940s, but the U.S. Environmental Protection Agency banned the use of CCA in residential wood products commencing on December 31, 2003. The EPA lists three alternatives to CCA—borates, copper azole, and ACQ.

4.2.7.1 Borates—Disodium Octoborate Tetrahydrate (DOT)

Borates are low-toxicity, naturally occurring minerals that have marginal environmental impact. DOTs are effective decay fungicides and insecticides that prevent termite infestation. They are used in aboveground applications such as sill plates, furring strips, joists, and sheathing. Often borate is referred to as inorganic boron, abbreviated as SBX.

4.2.7.2 Copper Azole—A Water-Based Preservative

This is a water-based preservative acting as a fungicide and insecticide used as a wood preservative for softwoods such as southern pine, red pine, ponderosa pine, hem-fir, and Douglas fir. Applied to shingles, shakes, plywood, structural lumber, fence posts, and freshwater pilings, copper azole leaves a paintable surface after it dries.

4.2.7.3 ACQ—also Water-Based

This preservative is also water-based and is available in different formulations to achieve compatibility for various wood species. All ACQ preservatives contain two active ingredients, copper oxide (62–71%), the primary fungicide, and a quaternary ammonium compound (29–38%) that provides additional insect resistance. ACQ is applied to lumber, timbers, fence posts, landscape ties, sea walls, decking, and wood shingles.

4.3.0 Redwood and Cypress

Redwood and cypress are two wood products that exhibit high resistance to decay and insect infestation. Both species are durable and present unique grain patterns and colors.

4.3.1 Redwood Grades

These grades include heartwood, sapwood, and grade markings.

Architectural

Heartwood

Clear All Heart
Finest architectural heartwood grade, normally Certified Kiln Dried (also available unseasoned), well manufactured, free of defects one face (reverse face may have slight imperfections). Available surfaced or saw-textured.

Uses Siding, paneling, trim, cabinetry, molding, fascia, soffits, millwork. Also fine decks, hot tubs, garden structures, industrial storage and processing tanks.

Heart B
Quality heartwood grade containing limited knots and other characteristics not permitted in Clear All Heart and Heart Clear. Available kiln dried or unseasoned. This grade can be surfaced or saw-textured.

Uses Siding, paneling, trim, fascia, molding and other architectural uses. Quality decking, garden shelters and other above-ground outdoor applications.

Sapwood

Clear
Same general quality as Clear All Heart except contains sapwood in varying amounts. Some imperfections not permitted in Clear All Heart. Normally Certified Kiln Dried (also available unseasoned). Available surfaced or saw-textured.

Uses Siding, paneling, trim, cabinetry, molding, fascia, soffits. Also quality decking, garden shelters and other above-ground applications.

B Grade
Quality grade containing sapwood, limited knots and other characteristics not permitted in Clear. Certified Kiln Dried; also unseasoned. Available surfaced or saw-textured.

Uses Siding, paneling, trim, fascia, molding and other architectural uses; quality decking, garden shelters and other above-ground outdoor applications.

Redwood Grademarks
Standard grademarks include grade name and symbol of authorized grading agency. Grademarks may be on seasoned or unseasoned lumber on face, edge or end of piece. "Certified Kiln Dried" marks lumber kiln dried to accepted RIS standards.





CRA trademark on products of member mills of California Redwood Association, is an additional assurance of quality.

Garden

Construction Heart/Deck Heart
A heartwood grade containing knots of varying sizes and other slight imperfections. Available seasoned or unseasoned. This highly useful grade can be ordered surfaced or rough.

Deck Heart has similar appearance and uses as Construction Heart but is also graded for strength. Deck Heart is available in 2x4 and 2x6 only.

Uses Decks, posts, retaining walls, fences, garden structures, stairs or other outdoor uses especially on or near soil.

Merchantable Heart
This economical heartwood grade allows slightly larger knots than construction grades; holes limited to size of knots. Allows checks, some splits and some manufacturing flaws. Available unseasoned, surfaced or rough.

Uses Fences, retaining walls, garden structures—especially on or near soil.

Construction Common/Deck Common
Same general characteristics as Construction Heart, but contains combination of heartwood and sapwood. Unseasoned or seasoned, it can be surfaced or rough.

Deck Common is also graded for strength and is available in 2x4 and 2x6 only.

Uses Decking, fence boards and other above-ground garden uses that do not require heartwood's insect and decay resistance.

Merchantable
Has same characteristics as Merchantable Heart but contains sapwood in varying amounts. This economical grade is available unseasoned and can be ordered surfaced or rough.

Uses Fence boards, rails and other above-ground outdoor and garden uses. Also subflooring and temporary construction.

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4.3.2 Dimensional Stability of California Redwood

Dimensional Stability of California Redwood

Redwood has the least volumetric shrinkage of any commercial domestic wood; therefore, it can be subjected to considerably more change in moisture before it has the same change in dimensions as other commercial species. This means that projects manufactured with redwood will be much less subject to open joints, warping, cupping, splitting and other defects associated with dimensional change. Table 1 provides relative shrinkage values for a number of common domestic softwoods. These values are shown on a relative basis taking the values for old-growth redwood as 100 percent. Values over 100 indicate shrinkage greater than that for old-growth redwood.

Table 1. Average relative shrinkage values for common domestic softwoods

Species	Shrinkage from green to oven-dry condition based on dimensions when green		
	Radial	Tangential	Volumetric
Redwood, old growth	100	100	100
Redwood, young growth	85	111	103
Western redcedar	92	114	100
White fir	127	159	144
Baldcypress	146	141	154
Ponderosa pine	150	141	143
Douglas-fir (coastal)	185	173	182
Southern pine (loblolly)	185	168	181
Western hemlock	162	177	182

Water exists in green (unseasoned) wood in two conditions: as free water in the cell cavities and as bound water in the cell walls. When wood contains just enough water to saturate the cell walls, it is said to be at the fiber saturation point (FSP). Water in excess of this amount cannot be absorbed by the cell walls.

By permission, California Redwood Association, Novato, California.

4.3.3 Kiln-Dried Siding Application Checklist



Certified Kiln Dried Siding Application Checklist

Wood is a product of nature, so individual pieces vary in performance. Siding is a single component of a building. Its performance is dependent upon many critical factors including: the structure's design, the craftsmen's skills, the use of other materials, the siding's exposure and the local climate.

This checklist was designed to help builders track some of the factors that affect the performance of Certified Kiln Dried redwood siding. Following these guidelines will improve the performance of CKD redwood siding and will extend its service life.

Store it right

- ☐ Store it dry, off the ground and under cover but with proper air circulation. In the building or garage is ideal.
- ☐ Loosen factory wrappers while storing.
- ☐ Store on site for about 15 to 30 days to let the moisture content of the siding reach an equilibrium with the atmosphere.
- ☐ Prevent siding from getting wet or dirty.

Use proper wall construction

- ☐ Include a vapor barrier with a rating of 1 perm or less on the warm side of the wall.
- ☐ Install water-resistant building paper with a rating of 5 perms or greater over sheathing.
- ☐ Use fiberboard, plywood, OSB or waferboard sheathing.
- ☐ Apply finish to all faces, ends and edges before siding installation.

Use the right nails

- ☐ Use noncorrosive nails to avoid nail stains. . .stainless steel, aluminum or top-quality, hot-dipped galvanized are required.
- ☐ Use ringed-shank, wood siding nails for adequate holding power.
- ☐ Use nails that penetrate 1½ inches into framing members or a combination of solid wood sheathing and framing.
- ☐ If sheathing is not wood based, use longer nails to achieve the required 1½-inch penetration.

4.3.3 Kiln-Dried Siding Application Checklist (Continued)

- [ ] Pre-drill nail holes at ends to prevent splitting.
- [ ] Do not use staples; they do not provide adequate holding power and are seldom non-corrosive.

Install it right

- [ ] *Plain Bevel:* Give courses a 1-inch overlap. Use one nail per bearing and drive the nail so that it clears the top of the preceding course by about 1/8 inch.
- [ ] *Rabbeted Bevel*: Use one nail per bearing and place the nail about one inch above the lower edge of the course.
- [ ] *V Shiplap wider than 6 inches*: Face nail with two siding nails per bearing. Place nails one quarter the width of the material in from each edge.
- [ ] *V Shiplap 6 inches or less*: Use one nail per bearing. Place the nail one inch from the overlapping edge.
- [ ] *Channel Shiplap 6 inches*: Use one nail one inch from the lap.
- [ ] *Channel Shiplap 8 inches*: Face nail with two nails per bearing. Place nails 1 1/2 inches from the edge of the overlap and 2 inches from the edge of the underlap. Nail wider patterns proportionately.
- [ ] *Tongue & Groove wider than 6 inches*: Face nail with two siding nails per bearing.
- [ ] *Tongue & Groove siding 6 inches or less*: Blind-nail through the tongue with finish nails.
- [ ] For rabbeted bevel and channel shiplap patterns, provide 1/8 inch expansion clearance between courses.
- [ ] For patterns installed vertically, nail boards to horizontal blocking installed between studs at no more than 24 inches on center.

Finish it right

- [ ] Use top quality paints and finishes.
- [ ] Back prime each board *before* installation.
- [ ] Factory priming or prefinishing is recommended.
- [ ] Oil-based exterior stains should contain a water repellent. A mildewcide and an ultraviolet inhibitor are recommended.
- [ ] Apply finishes with a brush to work the finish well into the wood. A roller is the next best applicator. Do not spray as this does not provide adequate coverage.

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4.4.0 Cypress

Cypress is a conifer with excellent watertight durability and was often used in making barrels. This wood is highly resistant to decay and insect infestation. There are several types of commercial cypress. Cypress is sold as #2 or better and select grades.

4.4.1 Common Bald Cypress

Common bald cypress is found in deep swamps in the lower Atlantic coastal plains and is well suited for greenhouse planking, boat building, shingles, posts, poles, and cross-ties.

4.4.2 Pond Cypress

Pond cypress is found in wet sites and is very similar in appearance and qualities to bald cypress.

4.4.3 Atlantic White Cedar

Atlantic white cedar is now a scare commodity and is often found in year-round swampy areas in New England and in other areas southward to Florida. This wood is slightly fragrant and is ideal for boat and canoe construction, shingles, and fence posts.

4.4.4 Red Cedar Heartwood

Red cedar heartwood is distinctly red with contrasting white sapwood. This lumber is frequently used in clothes closet construction and interior wood trim.

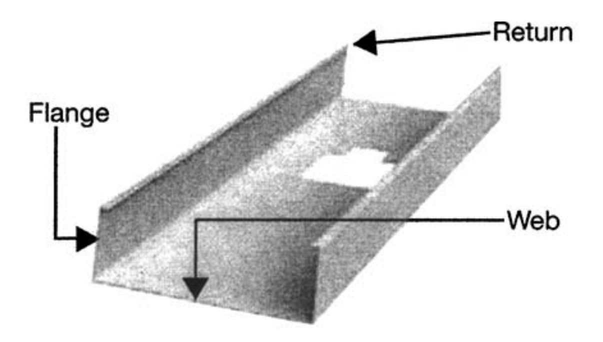
4.4.5 Southern Red Cedar

Southern red cedar is similar in color and nature to red cedar, and as the name implies, it is found in the southern part of the United States, primarily in Florida. Aromatic and repellent to insects, along with red cedar, this species also finds application in closet construction and is widely used in the manufacture of pencils.

4.5.0 Steel Framing for Interior Partition or Exterior Wall Construction

Steel framing includes metal gauges from 12 to 25 gauge and member sizes from 7/8-in. drywall furring channels to 16-in. structural stud wall framing and metal trusses.

4.5.1 Common Steel Framing Terms



Common Steel Framing Terms

Wooden boards are described as having faces and edges. Steel studs are described differently. Please note the following differences:

- Instead of a face, a steel stud has a web
- Instead of edges, steel studs have flanges and returns

Metal track also has its own terminology. Features of metal track are described in the following way:

- Instead of a face, metal track also has a web dimension
- What are called flanges on metal studs are known as legs for track
- Studs are manufactured in lengths ranging from 8′ to 24′

Most building centers only stock steel studs in 8′, 10′ and 12′ lengths. Track is available only in 10′ lengths. Large orders may be cut to size at the factory.



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4.5.2 Drywall Track and Studs—Common Dimensions

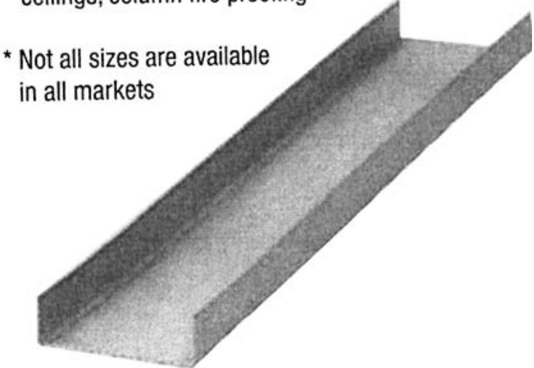
Drywall Track*

- Size: (Web): 1-5/8″, 2-1/2″, 3-1/2″, 3-5/8″, 4″, 5-1/2″ and 6″
- Gauge: 25 EQ, 20 DW EQ and 20 STR EQ
- Flange: 1-1/4″, 2″ and 3″
- Market Synonyms: Runner, Plate, Drywall Track (DWT) and Cold Runner (CR)
- Applications: Drywall track is attached to floors and ceilings to hold studs in place

Drywall Stud*

- Size: (Web): 1-5/8″, 2-1/2″, 3-1/2″, 3-5/8″, 4″, 5-1/2″ and 6″
- Gauge: 25 EQ, 20 DW EQ and 20 STR EQ
- Flange: 1-1/4″
- Market Synonyms: Tin Can, Drywall Stud (DWS) SS, Light Gauge Stud (LGS)
- Applications: Non-structural partition walls, ceilings, column fire proofing

* Not all sizes are available in all markets



By permission, Dietrich Industries, Pittsburgh, PA.

Dietrich UltraSTEEL® Framing's 20 DW-Gauge EQ Composite Limiting Heights (1 layer 1/2" thick gypsum wallboard)[1]

Stud Member	Spacing (in.)	5 psf			7.5 psf			10 psf			15 psf		
		L/120	L/240	L/360	L/120	L/240	L/360	L/120	L/240	L/360	L/120	L/240	L/360
162 USTE	12	17' 4"	13' 9"	12' 0"	15' 2"	12' 0"	7' 7"	13' 9"	8' 9"	–	12' 0"	–	–
	16	12' 8"	10' 1"	8' 10"	11' 1"	8' 10"	7' 8"	10' 1"	8' 0"	–	8' 10"	–	–
	24	14' 0"	9' 0"	–	12' 3"	–	–	9' 0"	–	–	–	–	–
250 USTE	12	19' 10"	15' 9"	13' 6"	17' 4"	13' 6"	10' 8"	15' 9"	11' 5"	9' 1"	13' 6"	9' 1"	–
	16	16' 5"	13' 0"	11' 4"	14' 4"	11' 4"	9' 11"	13' 0"	10' 4"	9' 0"	9' 5" f	9' 0"	7' 10"
	24	16' 0"	11' 10"	9' 5"	14' 0"	9' 5"	7' 8"	11' 10"	8' 1"	–	9' 5"	–	–
362 USTE	12	22' 0"	17' 5"	15' 1"	19' 2"	15' 1"	12' 10"	17' 5"	13' 5"	11' 5"	15' 1"	11' 5"	9' 9"
	16	19' 4"	15' 4"	13' 5"	16' 11"	13' 5"	11' 9"	15' 4"	12' 2"	10' 8"	12' 11" f	10' 8"	9' 3"
	24	17' 8"	13' 8"	11' 7"	15' 5"	11' 7"	9' 11"	13' 8"	10' 4"	8' 10"	11' 7"	8' 10"	7' 7"
400 USTE	12	24' 3"	19' 3"	16' 9"	21' 2"	16' 9"	14' 8"	19' 3"	15' 3"	13' 2"	16' 9"	13' 2"	11' 3"
	16	21' 9"	17' 3"	15' 0"	19' 0"	15' 0"	13' 2"	17' 3"	13' 8"	11' 11"	15' 0"	11' 11"	10' 5"
	24	19' 5"	15' 5"	13' 3"	17' 0"	13' 3"	11' 1"	15' 5"	11' 8"	9' 10"	12' 10" f	9' 10"	8' 3"
600 USTE	12	30' 8"	24' 4"	21' 3"	26' 9"	21' 3"	18' 7"	24' 4"	19' 4"	16' 10"	21' 3"	16' 10"	14' 7"
	16	28' 0"	22' 3"	19' 5"	24' 6"	19' 5"	17' 0"	22' 3"	17' 8"	15' 5"	18' 9" f	15' 5"	13' 5"
	24	25' 0"	19' 10"	17' 4"	21' 10" f	17' 4"	14' 10"	18' 11" f	15' 7"	13' 2"	14' 3" s	13' 2"	11' 3"

f: Flexural stress controls allowable wall height s: Shear/web crippling control allowable wall height Minimum yield strength = 40 ksi

[1] Composite limiting heights based on single layer 1/2" thick gypsum board full height on each side with screws spaced 12" O.C. to framing members per ASTM C 754. Tested to ICC acceptance criteria AC86

By permission, Dietrich Industries, Pittsburgh, PA.

Dietrich UltraSTEEL® Framing's 25-Gauge EQ Composite Limiting Heights (1 layer 1/2" thick gypsum wallboard)[1]

Stud Member	Spacing (in.)	5 psf			7.5 psf			10 psf			15 psf		
		L/120	L/240	L/360	L/120	L/240	L/360	L/120	L/240	L/360	L/120	L/240	L/360
162 USTN	12	12'-6"	9'-11"	8'-8"	10'-11"	8'-8"	–	9'-11"	7'-11"	–	8'-8"	–	–
	16	11'-4"	9'-0"	7'-11"	9'-11"	7'11"	–	9'-0"	–	–	–	–	–
	24	9'-11"	7'-11"	–	8'-8"	–	–	7'-11"	–	–	–	–	–
250 USTN	12	15'-8"	12'-5"	10'-10"	13'-8"	10'-10"	9'-6"	12'-4" f	9'-11"	8'-8"	10'-1" f	8'-8"	–
	16	14'-2"	11'-3"	9'-10"	12'-5"	9'-10"	8'-7"	11'-3"	8'-11"	7'-10"	8'-11" s	7'-10"	–
	24	12'-4"	9'-10"	8'-7"	10'-9"	8'-7"	–	9'-9" f	7'-9"	–	–	–	–
362 USTN	12	20'-10"	16'-7"	14'-3"	18'-3"	14'-3"	12'-3"	16'-3" f	12'-10"	11'-0"	12'-10" f	11'-0"	9'-6"
	16	19'-1"	15'-1"	12'-10"	16'-5" f	12'-10"	11'-0"	13'-11" f	11'-6"	9'-11"	11'-0" f	9'-11"	8'-6"
	24	16'-6" f	12'-11"	11'-0"	13'-1" f	11'-0"	9'-5"	11'-2" f	9'-11"	8'-6"	8'-10"	8'-6"	–
400 USTN	12	22'5"	17'-9"	15'-6"	19'-7"	15'-6"	13'-2"	17'-0" f	13'-10"	11'-9"	13'-4" s	11'-9"	10'-1"
	16	20'-6"	16'-3"	13'-10"	17'-0" f	13'-10"	11'-9"	14'-6"	12'-4"	10'-6"	11'-1" s	10'-6"	9'-0"
	24	17'-1" f	13'-11"	11'-9"	13'-8" f	11'-9"	10'-10"	11'-7" f	10'-6"	9'-0"	8'-11" s	8'-11" s	–
600 USTN	12	29'-10"	23'-8"	20'-9"	24'-7" f	20'-9"	18'-1"	20'-9" s	18'-10"	16'-5"	13'-10" s	13'-10" s	13'-10" s
	16	25'-7" f	21'-6"	18'-9"	20'-11" f	18'-9"	16'-5"	17'-1" s	17'-1" s	14'-8"	11'-5" s	11'-5" s	11'-5" s
	24	20'-6" f	18'-9"	16'-5"	16'-9"	16'-5"	13'-10"	13'-5" s	13'-5" s	12'-3"	9'-0" s	9'-0" s	9'-0" s

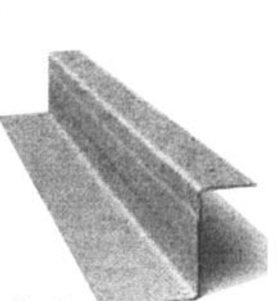
f: Flexural stress controls allowable wall height s: Shear/web crippling control allowable wall height Minimum yield strength = 40 ksi

[1] Composite limiting heights based on single layer 1/2" thick gypsum board full height on each side with screws spaced 12" O.C. to framing members per ASTM C 754. Tested to ICC acceptance criteria AC86

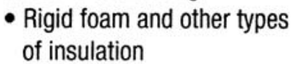
4.5.2.2 Resilient Channels, Z-Furring, and U Channel

Resilient Channel
Size: 1/2″ (Single Leg and Double Leg)
Gauge: 25 and 20
Market Synonyms:
- RC-1
- RC-2
- RC Channel
- Sound Channel

Z-Furring
Size: 1″, 1-1/2″, 2″ and 2-1/2″
Gauge: 25, 20, 18, 16, and 14
Applications: Dietrich Z-Furring Channel, made of 25 gauge, galvanized steel, is used to attach the following:



- Rigid foam and other types of insulation



- Gypsum panels
- Veneer gypsum base or conventional plaster base to the interior side of masonry walls
- Mineral fiber Z-furring insulation blankets when fire-resistant construction is required

U Channel
Size (Web): 3/4″, 1-1/2″, 2″ and 2-1/2″
Gauge: 16
Market Synonyms:
- Cold Rolled Channel/CRC
- Black Iron
- Horizontal Bracing

Applications: Dietrich U-Channel, made of 16-gauge steel, is used to laterally brace studs or with furring channels in ceiling applications. When used as lateral bracing, a clip angle is attached to both the stud and U-Channel to prevent stud rotation.

By permission, Dietrich Industries, Pittsburgh, PA.

4.5.2.3 Metal Corner Bead, Bullnose Corner Bead, Metal Trim, Tear-Away Beads

Metal Corner Bead & Trims
Size: 1-1/4″ x 1-1/4″ x 8′ or 10′

Corner Beads
Dietrich's 103 Deluxe and Quicksilver products are galvanized steel angles that ensure straight, protective, clean-finished drywall corners. They may be nailed or stapled into place, and can be completely concealed with joint compound.

The premium 103 Deluxe has a dull, electro-galvanized and wiped finish. The Quicksilver is a bright, hot-dip galvanized bead offering superior corrosion protection. Both models are supplied with holes for nail attachment.

Bullnose Corner Bead
Equipped with a 3/4″ radius for gently rounded corners, bullnose corner bead is available for 90 degree and 135 degree corners.

Metal Trims
Dietrich offers a wide array of metal trims, control joints as well as an extensive selection of casing beads for nearly every finishing condition.



Vinyl Beads



Vinyl beads and trims provide a exceptionally durable and moisture-resistant finish. Vinyl Corp is one of the largest full-line vinyl bead and trim manufacturers in the U.S. Product categories include vinyl beads, trims and control joints for stucco/plaster, drywall, exterior insulation finish systems (EIFS) and direct-applied Exterior Finish Systems (DFS).

J-Bead
J-Bead forms a finish at gypsum stops around door and window openings, and at ceiling intersections. When J-bead is used, no joint compound is necessary.

Tear-Away L-Bead
Tear-Away L-Bead provides an easy, top-quality finish at intersections of gypsum board and ceiling grid. Once joint compound is applied, the tear-away strip is removed to form a clean, crisp edge.

Corner Bead
Vinyl Corner Bead serves as a durable reinforcement for finishing square gypsum corners. It's flexibility resists dents and helps to speed the finishing process.

Bullnose Corner Bead
Bullnose Corner Bead creates a smooth rounded corner that resists dents, and will not corrode. Gypsum panels must be cut back 3/4″ to accommodate the bullnose radius.

Archway Corner Bead
Archway Corner Bead reinforces corners on radius windows and doors. The notched flange adapts to virtually any radius condition.

Paperfaced Corner Bead
By combining galvanized corner protection with high-grade paper-tape facing, paper faced corner beads provide superior compound-embedded fastening. Finished corners and edges are stronger than with metal or vinyl beads. Joint compound bonds with wallboard resisting edge cracking. Select a metal flange width that will successfully bridge and protect board ends and edges. Paper facing extends beyond the metal to bond securely with the wallboard face paper.

By permission, Dietrich Industries, Pittsburgh, PA.

4.5.2.4 Steel Framing Member Fasteners

Fasteners
Screws
Power Actuated Fasteners

A variety of screws and power-actuated fasteners can be used to connect framing components and also to fasten other materials to the framing.

Self-Drilling Screws
These externally threaded fasteners have the ability to drill their own hole and form, or "tap," their own internal threads without deforming their own thread and without breaking during assembly. These screws are used with 33-mil (20 gauge) steel or thicker.



Sharp-Point Screws
These externally threaded fasteners are self-piercing and are used to attach rigid materials, such as gypsum wallboard, and sub flooring. They are used with 25 and 20 gauge components.

Fasteners for Drywall Systems

Pan Head Type 'S' Framing Screws
- Used for attachment of steel stud to steel track

Bugle Head Type 'S' Drywall Screws
- Utilized for attachment of drywall to steel framing

Trim Head Type 'S' Trim Screw
- Used to attach wood trim to steel framing

Masonry Screws or Powder Actuated Fasteners
- Used to attach steel track to concrete floor

Fasteners for Steel to Steel and Wood to Steel

Pan Head
- 8 x 7/16 Framing Screw
- Used with 20-25 gauge steel
- Unique grip-tight, high-torque pan head



Hex Head 8 x 1/2
- Attaches fixtures, backup plates, door frames and lathers channel to structural studs, metal decks and trusses, etc.
- 20-14 gauge



Wafer Head
- 8 x 1/2
- Attaches metal K-lath, wire lath, wood grounds, etc. to lathers channel, structural studs, metal decks, etc.
- Used for attachment of steel studs to track 20-14 gauge



Wafer Head Winged
- 10 x 1-7/16
- Used to attach 3/16" to 3/4" plywood to 20-14 gauge metal



Bugle Head
- 10 x 1-7/16
- Used to attach 3/16" to 3/4" plywood to 20-14 gauge metal





By permission, Dietrich Industries, Pittsburgh, PA.

4.5.2.5 Drywall Furring Channel

Drywall Furring Channel
Size (Web): 7/8″ and 1-1/2″
Gauge: 25, 20, and 18
Market Synonyms:
- Hat Channel
- "DWC"
- High Hat
- Drywall Channel

Applications: Dietrich Drywall Furring Channel is a roll formed, hat-shaped section available in three gauges of galvanized steel. The DWC-25 channel is used for attachment of:
- Gypsum panels
- Veneer or conventional plaster base in ceiling construction
- Noncombustible furring for interior or exterior walls

Heavier FCE-20 and FCS-18 channels permit greater spans and load capacity. The channels are available in 7/8″ and 1-1/2″ depths.

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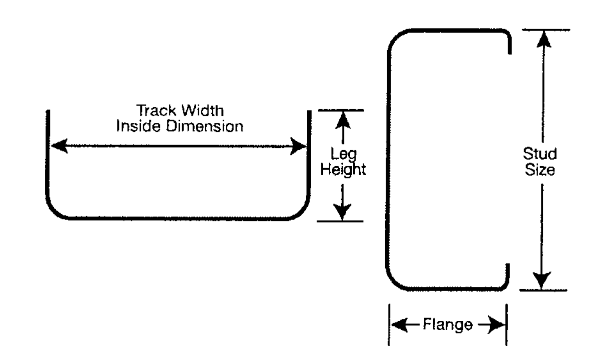
4.5.3 Structural Studs

Structural Studs, available in the following configurations:
- Web sizes ranging from 2-1/2″, 3-1/2″*, 3-5/8″, 4″, 5-1/2″*, 6″, 8″, 10″, 12″ and 14″
- Equal Flanges of 1 3/8″, 1-5/8″, 2″, 2-1/2″ and 3″
- Returns (lips) of 1/2″, 5/8″ and 1″
- Yield Strengths of 33 and 50 KSI
- Gauges of 20, 18, 16, 14 and 12

Structural Track (TSB), available in the following configurations:
- Matching Web sizes ranging from 2-1/2″ to 14″
- Standard leg heights of 1-1/4″ (unequal and equal leg heights up to 3″ are available upon request)
- Standard 10′ lengths (other lengths are available upon request) 33 and 50 KSI yield strengths also by special request, and gauges of 20, 18, 16, 14 and 12

Other sizes and gauges may be custom rolled as required. Call us for more information at 1-800-873-2443.

* Available in some markets.



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4.5.3.1 Structural Gauges for Load Bearing, Curtain Wall Framing, and Track

Structural Framing
Load Bearing and Curtain Wall Applications

Dietrich Metal Framing Big "D" Light Gauge Framing Systems offer the most diverse range of framing components available in the industry. The flexibility to choose from a wide selection of gauges, yield strengths, sizes and flange widths enables building designers to obtain optimal, cost-effective performance.

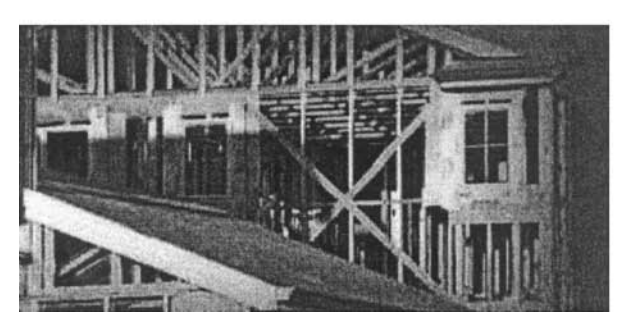
Lightweight steel framing from DMF can be assembled in a variety of ways to provide:
- Framing for curtain walls
- Axial loaded walls
- Floors
- Roof systems

Light gauge framing is ideal for use in:
- Low-rise and mid-rise construction
- Multifamily housing
- Most commercial, institutional and industrial structures

Structural or curtain wall framing is available in a variety of gauges, ranging from 20 to 12 gauge. The gauge or thickness is determined based on application, load and spacing.

Structural Gauges

Steel Thickness		Design Thickness		Minimum Thickness	
Gauge	Mils	in	mm	in	mm
20	33	0.0346	0.88	0.0329	0.84
18	43	0.0451	1.14	0.0428	1.08
16	54	0.0566	1.44	0.0538	1.37
14	68	0.0713	1.81	0.0677	1.72
12	97	0.1017	2.58	0.0966	2.45



Curtain Wall Framing

Curtain Wall Framing Systems support the exterior skin or cladding of commercial and industrial buildings. The studs for these framing systems must be able to withstand:
- The weight of the cladding material (metal, stone, tile, etc.)
- The wind loads to which they will be subjected

These studs do not support the floors and roof of a building.

Curtain Wall Studs – These are specifically designed for use in curtain wall applications. The 1-3/8" flange offers a sufficient surface for easy attachment of exterior cladding material. The studs also may be used in some light load-bearing situations.

Curtain Wall Studs are available in six standard web depths for added design flexibility:
- 2-1/2"
- 3-5/8"
- 4"
- 6"
- 8"

Gauges range from 20 to 12 (.033" - .097" thick). Additional sizes and gauges are available in some areas. Check with your Dietrich Sales Representative.

Structural Track

Web: 2-1/2", 3-1/2", 3-5/8", 4", 6", 8", 10", 12", 14" and 16"
Gauge: 20, 18, 16, 14 and 12
KSI Rating: 33 (50 KSI available by special request)
Applications:
- Axial Load Bearing Interior Walls
- Axial Load Bearing Exterior Walls
- Non-Axial Interior & Exterior Walls

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4.5.4 Steel Floor Joists

TradeReady® Floor System

TradeReady® Joist

Size:
- 1-3/4″ Flange 7-1/4″, 8″, 9-1/4″ and 11- 1/4″ depths
- 2″ Flange 10″, 12″, and 14″ depths

Gauge:
- 18
- 16
- 14
- 12

KSI:
- 33
- 50

Nomenclature:
- TDJ
- TDW

Flange:
- TDJ 1-3/4″ Flange
- TDW 2″ Flange

Applications:
- Floor Joist for the TRFS

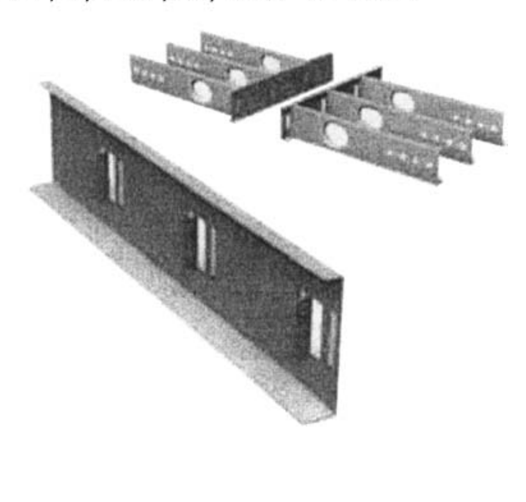


TradeReady® Rim

Size: 7-1/4″, 8″, 9-1/4″, 10″, 11-1/4″ 12″ and 14″

Gauge:
- 18
- 16
- 14
- 12

KSI:
- 33
- 50



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4.6.0 Gypsum Drywall Materials

4.6.1 Wood and Steel Framed Wall Assemblies

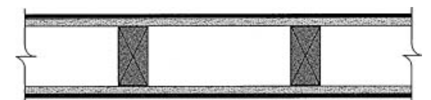
Architectural Assemblies



The following information in this catalog for wall partitions/wood studs, wall partitions/metal studs, and floor/ceiling assemblies has been organized for ease of reference. Installation details and technical data are located adjacent to each other. For more detailed information please reference the individual testing agencies' listings.

"Est." in the following information means estimated results. Check with local code jurisdictions or design authority before using or including in plans. CAUTION: For product fire, safety and use information, go to gp.com/safetyinfo.

Wood-Framed Wall Assemblies

45-Min. Fire Rating Test Reference: UL U317, cUL U317 	Partition Thickness: 4-5/8", Weight per Sq. Ft.: 6.0 1/2" ToughRock® Fireguard® Type C or 1/2" DensArmor Plus® Fireguard® Type C gypsum board applied parallel or at right angles to each side of 2 x 4 wood studs 16" o.c. with 1-5/8" cement coated nails spaced 7" o.c. Joints staggered.
1-Hour Fire Rating Test Reference: UL U305, ULC W301, GA WP 3605, cUL U305 	**30-34 STC Sound Trans.** Test Reference: OR 64-8 Partition Thickness: 4-7/8", Weight per Sq. Ft.: 7.0 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to each side of 2 x 4 wood studs 16" o.c. with 1-7/8" 6d coated nails spaced 7" o.c. Joints staggered.
1-Hour Fire Rating Test Reference: FM WP 90, GA WP 3520 	**35-39 STC Sound Trans.** Test Reference: G&H NG-246FT Partition Thickness: 4-7/8", Weight per Sq. Ft.: 7.0 5/8" ToughRock Fireguard Type X gypsum board or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel to each side of 2 x 4 wood studs 24" o.c. with 1-7/8" 6d coated nails 7" o.c. at joints and top and bottom plates and 3/8" beads of adhesive at intermediate studs. Joints staggered.
1-Hour Fire Rating Test Reference: UC, 1-12-66, GA WP 3620	**30-34 STC Sound Trans.** Test Reference: G&H IBI-35FT Partition Thickness: 4-7/8", Weight per Sq. Ft.: 7.0 **Sound Tested** without gypsum veneer plaster 1/2" ToughRock veneer base Type X applied at right angles to each side of 2 x 4 wood studs 16" o.c. with 1-3/4" 5d etched nails 8" o.c. 1/16" DensArmor Cote™ or Pearl Cote™ Interior Veneer Plaster applied over each face. Vertical joints staggered 16" and horizontal joints 12" on opposite sides.
1-Hour Fire Rating Test Reference: UL U338, GA WP 3640 	Partition Thickness: 2-7/8", Weight per Sq. Ft.: 7.0 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to each side of 2 x 3 or 2 x 4 wood studs, turned flatwise 24" o.c. with 1-7/8" 6d cement coated nails 7" o.c. (non load-bearing).

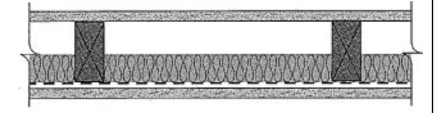
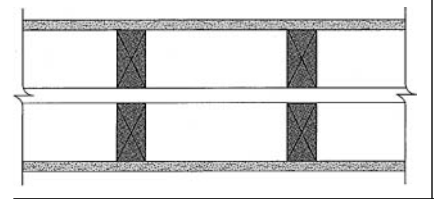
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4.6.1 Wood and Steel Framed Wall Assemblies (Continued)



Architectural Assemblies

Wood-Framed Wall Assemblies continued

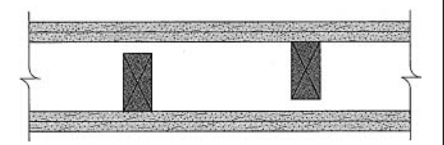
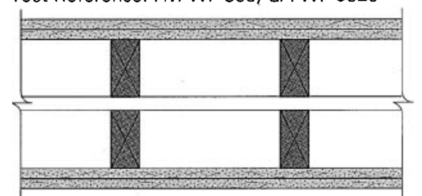
1-Hour Fire Rating Test Reference: OSU T-3127 	**50-54 STC Sound Trans.** Test Reference: RAL TL77-138 Partition Thickness: 5-1/4", Weight per Sq. Ft.: 7.0 **Sound Tested** with 3-1/2" fiberglass insulation 5/8" ToughRock® Fireguard Type X or 5/8" DensArmor Plus® Fireguard® Type X board applied parallel to resilient channels 24" o.c. with 1" Type S drywall screws at edges 6" o.c. and center row 12" o.c. at intermediate studs. End joints back-blocked with resilient channels. Resilient channels attached at right angles to 2 x 4 wood studs 16" o.c. with 1-7/8" 6d coated nails. 1/2" x 3" gypsum board filler strip attached to plate at floor line with 6d coated nails 16" o.c. 1-1/2" fiberglass 0.8 pcf attached to studs in stud space with 1/2" long staples. On opposite side, one layer 5/8" ToughRock Fireguard or 5/8" DensArmor Plus Fireguard Type X gypsum board applied at right angles to studs with 6d coated nails, 8" o.c. Stagger end joints 48" o.c. each side.
1-Hour Fire Rating Test Reference: UL U305, ULC W301, GA WP 5515 	**40-44 STC Sound Trans.** Test Reference: Est. Partition Thickness: 7-3/4", Weight per Sq. Ft.: 8.0 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to each side of 2 x 4 wood studs 16" o.c. staggered 8" o.c. on 2 x 6 wood plates with 1-7/8" 6d coated nails 7" o.c. Wallboard nailed to top and bottom plates 7" o.c. Stagger joints each side. Horizontal bracing required at mid height.
1-Hour Fire Rating Test Reference: UL U305, ULC W301, GA WP 5512 	**45-49 STC Sound Trans.** Test Reference: Est. Partition Thickness: 9-1/4", Weight per Sq. Ft.: 8.0 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to each side of double row of 2 x 4 wood studs 16" o.c. on separate plates 1" apart with 1-7/8" 6d coated nails 7" o.c. Wallboard nailed to top and bottom plates 7" o.c. Stagger joints each side. Horizontal bracing required at mid height.
2-Hour Fire Rating Test Reference: UL U301, cUL U301 	**40-44 STC Sound Trans.** Test Reference: NGC-2363 Partition Thickness: 6-1/8", Weight per Sq. Ft.: 12.0 **Sound Tested** with studs 16" o.c. and with nails for base layer spaced 6" o.c. Base Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied vertically or at right angles using 1-7/8" 6d coated nails 6" o.c. to each side of 2 x 4 wood studs 16" o.c. Face Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied vertically or at right angles to studs over base layer with 2-3/8" 8d coated nails 8" o.c. Stagger joints 16" o.c. each layer and side.

4.6.1 Wood and Steel Framed Wall Assemblies (Continued)

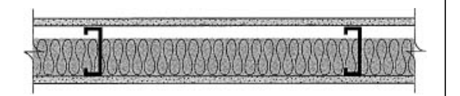
Architectural Assemblies



Wood-Framed Wall Assemblies continued

2-Hour Fire Rating Test Reference: FM WP 360, GA WP 3910 	**50-54 STC Sound Trans.** Test Reference: NGC-2377 Partition Thickness: 8″, Weight per Sq. Ft.: 13.0 **Sound Tested** with nails for base layer spaced 6″ o.c. Base Layer: 5/8″ ToughRock® Fireguard® Type X or 5/8″ DensArmor Plus® Fireguard® Type X gypsum board applied at right angles to each side of 2 x 4 wood studs 16″ o.c. staggered 8″ o.c. on 2 x 6 wood plates with 1-7/8″ 6d coated nails 24″ o.c. Face Layer: 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied at right angles to studs with 2-3/8″ 8d coated nails 8″ o.c. Stagger vertical joints 16″ o.c. each layer and side. Horizontal bracing required at mid height.
2-Hour Fire Rating Test Reference: FM WP 360, GA WP 3820 	**55-59 STC Sound Trans.** Test Reference: NGC-3056 Partition Thickness: 10-3/4″, Weight per Sq. Ft.: 13.0 **Sound Tested** with 3-1/2″ fiberglass insulation stapled to studs in stud spaces on one side. Base Layer: 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied at right angles to each side of double row of 2 x 4 wood studs 16″ o.c. on separate plates 1″ apart with 1-7/8″ 6d coated nails 24″ o.c. Face Layer: 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board or 5/8″ DensShield® Fireguard® Type X Tile Backer applied at right angles to each side with 2-3/8″ 8d coated nails 8″ o.c. Stagger vertical joints 16″ o.c. each layer and side. Horizontal bracing required at mid height.

Steel-Framed Wall Assemblies

1-Hour Fire Rating Test Reference: ULC W412, GA WP 1070 	**45-49 STC Sound Trans.** Test Reference: RAL TL69-42 Partition Thickness: 3-1/2″, Weight per Sq. Ft.: 5.0 **Sound Tested** with 2″ mineral fiberglass insulation 1/2″ ToughRock Fireguard Type C gypsum board applied parallel to each side of 2-1/2″ steel studs 24″ o.c. with 1″ Type S drywall screws 8″ o.c. at vertical joints and 12″ o.c. at intermediate studs. 1-1/2″ mineral fiber insulation, stapled to board in stud space. Joints staggered.
1-Hour Fire Rating Test Reference: UL U465, ULC W415, GA WP 1081 	**48 STC Sound Trans.** Test Reference: RAL TL99-103 Partition Thickness: 4-7/8″, Weight per Sq. Ft.: 5.0 **Sound Tested** with 3″ mineral fiber, 2.5 pcf, in stud space. 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied vertically to each side of 3-5/8″ steel studs 24″ o.c. with 1″ Type S drywall screws 8″ o.c. at edges and 12″ o.c. at intermediate studs.
1-Hour Fire Rating Test Reference: UL V 450 	Partition Thickness: 2-7/8″, Weight per Sq. Ft.: 5.0 5/8″ DensArmor Plus Fireguard Type X gypsum board applied vertically to each side of 3-5/8″ UltraSTEEL® studs 24″ o.c. with 1″ Type S drywall screws 8″ o.c. at edges and 12″ o.c. at intermediate studs.

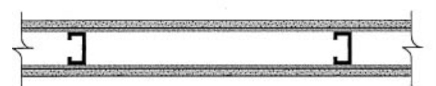
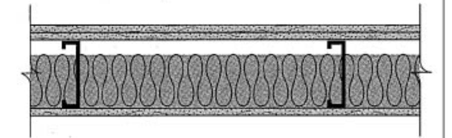
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4.6.1 Wood and Steel Framed Wall Assemblies (Continued)



Architectural Assemblies

Steel-Framed Wall Assemblies continued

1-Hour Fire Rating Test Reference: UC 12-28-65, GA WP 1090 	**45-49 STC Sound Trans.** Test Reference: ACI 7-115 2019c Partition Thickness: 3-1/8", Weight per Sq. Ft.: 7.0 Base Layer: 1/4" ToughRock® gypsum board applied parallel to each side of 1-5/8" steel studs 24" o.c. with 1" Type S drywall screws 24" o.c. at vertical joints and 36" o.c. at intermediate studs. Face Layer: 1/2" ToughRock® Fireguard® Type C or 1/2" DensArmor Plus® Fireguard® Type C gypsum board applied parallel to each side with 1-5/8" Type S drywall screws 12" o.c. Stagger joints.
1-Hour Fire Rating Test Reference: WHI 495-0614, GA WP 1023 	**50-54 STC Sound Trans.** Test Reference: RAL TL88-54 Partition Thickness: 5-5/8", Weight per Sq. Ft.: 7.0 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied at right angles to one side of 3-5/8" steel studs 24" o.c. with 1" Type S drywall screws 8" o.c. to vertical joints and 12" o.c. to intermediate studs. Studs attached to top and bottom runner with Type S pan head screws. Opposite Side Base Layer: 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied at right angles to studs with 1" Type S drywall screws 24" o.c. Face Layer: 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied at right angles to framing with 1-5/8" Type S drywall screws 8" o.c. at end joints and 12" o.c. at perimeter and intermediate studs. Stagger vertical joints 24" o.c. Stagger horizontal joints 24" o.c. each layer and side. Fiberglass insulation, 2-3/4" thick, 0.30 pcf, friction fit in stud space.
1-Hour Fire Rating Test Reference: OSU T-1770, GA WP 1052 	**50-54 STC Sound Trans.** Test Reference: NRCC 817-NV Partition Thickness: 5-1/2", Weight per Sq. Ft.: 8.0 **Sound Tested** with 3-1/2" fiberglass insulation friction fit in stud space 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard® Type X gypsum board applied parallel or at right angles to each side of 3-5/8" steel studs 24" o.c. with 1" Type S drywall screws 8" o.c. at vertical joints and 12" o.c. at wall perimeter and intermediate studs. Studs attached to top and bottom runner with Type S pan head screws. Face Layer: 5/8" ToughRock Fireguard Type X gypsum board or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to one side with 1-5/8" Type S drywall screws 12" o.c.
1-Hour Fire Rating Test Reference: UL U420, GA WP 5015, cUL U420 	**50-54 STC Sound Trans.** Test Reference: RAL TL76-155 Partition Thickness: 10-3/4", Weight per Sq. Ft.: 5.5 **Sound Tested** with 3-1/2" fiberglass insulation, stapled to one side in cavity 5/8" ToughRock® Fireguard® Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel to a double row of 1-5/8" steel studs 24" o.c. and not less than 1" apart with 1" Type S drywall screws 8" o.c. at edges and top and bottom runners, 12" o.c. in field. Stagger joints 24" each side. 5/8" gypsum board pieces 12" long x 4-1/2" wide located at 1/3 points used as cross braces fastened to stud pairs with three 1" Type S drywall screws at each end of brace. Optional 25-gauge, stud or runner pieces not less than 4-1/2" long may be used as cross braces and attached with two No. 8, 1/2" self-drilling steel screws at each end.

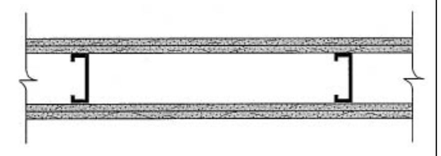
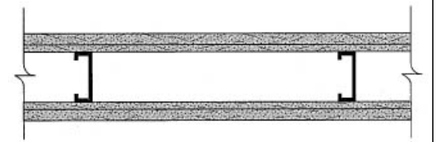
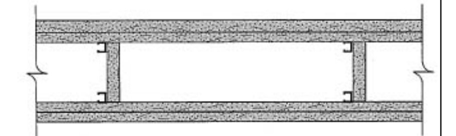
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4.6.1 Wood and Steel Framed Wall Assemblies (Continued)



Architectural Assemblies

Steel-Framed Wall Assemblies continued

2-Hour Fire Rating Test Reference: ULC W414, GA WP 1546 	**55-59 STC Sound Trans.** Test Reference: NRCC 815-NV Partition Thickness: 4-1/2", Weight per Sq. Ft.: 9.0 **Sound Tested** with 3-1/2" fiberglass insulation, friction fit in 3-5/8" stud cavity Base Layer: 1/2" ToughRock® Fireguard® Type C or 1/2" DensArmor Plus® Fireguard® Type C gypsum board applied parallel to each side of 2-1/2" steel studs 24" o.c. with 1" Type S drywall screws 24" o.c. Face Layer: 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied parallel to each side with 1-5/8" Type S drywall screws 12" o.c. Joints staggered 24" each layer and side.
2-Hour Fire Rating Test Reference: ULC W404, GA WP 1505 	**55-59 STC Sound Trans.** Test Reference: DRC 70-18-2 Partition Thickness: 4-3/4", Weight per Sq. Ft.: 10.0 **Sound Tested** with adhesive attachment and 2-1/2" fiberglass insulation, friction fit in stud space Base Layer: 1/2" ToughRock Fireguard Type C gypsum board applied at right angles to each side of 2-1/2" steel studs 24" o.c. with 1" Type S drywall screws 12" o.c. Face Layer: 5/8" ToughRock Fireguard Type X gypsum board applied parallel to each side. Vertical joints midway between studs. Face layer attached to base layer only with 1-1/2" Type G drywall screws 12" o.c. at vertical joints and center line of face layer gypsum board. 3/8" to 1/2" diameter adhesive beads around the perimeter of face board, 2" from each edge and end, and in the form of an X joining the corners of the perimeter beads are optional. Joints staggered 24" each layer and side.
2-Hour Fire Rating Test Reference: UL U420, GA WP 5105, cUL U420 	**55-59 STC Sound Trans.** Test Reference: RAL TL76-156 Partition Thickness: 12", Weight per Sq. Ft.: 10.0 **Sound Tested** with 3-1/2" fiberglass insulation stapled in stud space Base Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus® Fireguard® Type X applied parallel to a double row of 1-5/8" steel studs 24" o.c. and not less than 1" apart with 1" Type S drywall screws 8" o.c. at edges and 12" o.c. at intermediate studs. 5/8" gypsum board pieces 12" long x not less than 4-1/2" wide located at 1/3 points used as cross braces fastened to stud pairs with three 1" Type S drywall screws at each end of brace. Optionally 25-gauge stud or runner pieces, not less than 4-1/2" long, may be used as cross braces and attached with two No. 8 x 1/2" self-drilling steel screws at each end. Where total cavity depth exceeds 9-1/2", cross braces shall be fabricated with 25-gauge stud or runner pieces. Face Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X applied parallel to each side with 1-5/8" Type S drywall screws 8" o.c. at joints and floor and ceiling runners and 12" o.c. at intermediate studs.

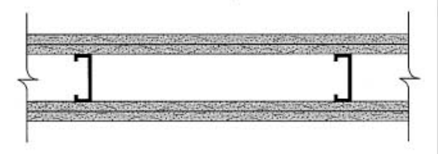
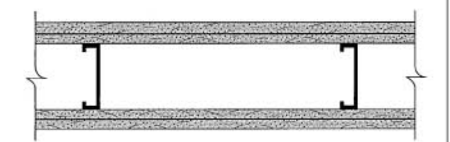
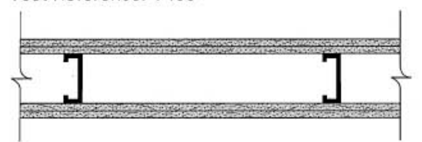
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4.6.1 Wood and Steel Framed Wall Assemblies (Continued)

Architectural Assemblies



Steel-Framed Wall Assemblies continued

2-Hour Fire Rating Test Reference: UL U411, cUL U411 	**50-54 STC Sound Trans.** Test Reference: WHI 218-1 Partition Thickness: 5-1/8", Weight per Sq. Ft.: 10.0 **Sound Tested** with 2-1/2" fiberglass insulation Base Layer: 5/8" ToughRock® Fireguard® Type X or 5/8" DensArmor Plus® Fireguard® Type X gypsum board applied parallel to each side of 2-1/2" steel studs 24" o.c. with 1" Type S screws 16" o.c. Face Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel to each side with drywall adhesive or secured with 1-5/8" Type S screws 12" o.c. at top and bottom track, 16" o.c. at edge joints and intermediate framing. Stagger joints 24" each layer and side.
2-Hour Fire Rating Test Reference: UL U411, cUL U411, GA WP 1522 	**55-59 STC Sound Trans.** Test Reference: NRCC 818-NV Partition Thickness: 6-1/8", Weight per Sq. Ft.: 10.0 **Sound Tested** with 3-1/2" fiberglass insulation, friction fit in 3-5/8" stud space Base Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel to each side of 2-1/2" steel studs 24" o.c. with 1" Type S screws 16" o.c. Face Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied parallel to each side with drywall adhesive or secured with 1-5/8" Type S screws 12" o.c. at top and bottom track, 16" o.c. at edge joints and intermediate framing. Stagger joints 24" each layer and side.
2-Hour Fire Rating Test Reference: V450 	Partition Thickness: 48-1/8", Weight per Sq. Ft.: 10.0 Base Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied at right angles to each side of 1-5/8" UltraSTEEL® studs 24" o.c. with 1-1/4" Type S screws 24" o.c. Face Layer: 5/8" ToughRock Fireguard Type X or 5/8" DensArmor Plus Fireguard Type X gypsum board applied at right angles to each side with 1-5/8" Type S screws 8" o.c. at end joints and 12" o.c. at perimeter. Stagger joints 12" each layer.
2-Hour Fire Rating Test Reference: UL U412 	**45-49 STC Sound Trans.** Test Reference: NGC 2250 Partition Thickness: 4-1/2", Weight per Sq. Ft.: 9.0 Base Layer: 1/2" ToughRock® Fireguard® Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied parallel to each side of 1-5/8" steel studs 24" o.c. with 1" Type S drywall screws 24" o.c. Face Layer: 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied parallel to each side with 1-5/8" Type S drywall screws 12" o.c. Joints staggered 24" each layer and side.
2-Hour Fire Rating Test Reference: ULC W414, GA WP 1546 	**50-54 STC Sound Trans.** Test Reference: NRCC 798-NV Partition Thickness: 4-1/2", Weight per Sq. Ft.: 9.0 **Sound Tested** with 2-1/2" fiberglass insulation stapled in stud space Base Layer: 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied parallel to each side of 2-1/2" steel studs 24" o.c. with 1" Type S drywall screws 24" o.c. Face Layer: 1/2" ToughRock Fireguard Type C or 1/2" DensArmor Plus Fireguard Type C gypsum board applied parallel to each side with 1-5/8" Type S drywall screws 12" o.c. Joints staggered 24" each layer and side.

4.6.1 Wood and Steel Framed Wall Assemblies (Continued)

Architectural Assemblies



Steel-Framed Wall Assemblies continued

2-Hour Fire Rating Test Reference: OSU T-1339 	**35-39 STC Sound Trans.** Test Reference: NGC 2359 Partition Thickness: 2″, Weight per Sq. Ft.: 9.0 1/2″ ToughRock® Fireguard® Type C or 1/2″ DensArmor Plus® Fireguard® Type C gypsum board applied parallel to each side of 1″ DensGlass™ Ultra Shaftliner Fireguard Type X with laminating compound combed over entire surface. Floor and ceiling track of wood or steel runners. Joints staggered.
3-Hour Fire Rating Test Reference: WHI-495-0785 & 0789 	**50-54 STC Sound Trans.** Test Reference: WEAL 87-118 Partition Thickness: 4-5/8″, Weight per Sq. Ft.: 13.0 Base Layer: 1/2″ ToughRock Fireguard Type C gypsum board applied parallel to each side of 1-5/8″ metal studs 24″ o.c. with joints staggered 24″ each side using 1″ Type S drywall screws 12″ o.c. Second Layer: 1/2″ ToughRock Fireguard Type C gypsum board applied parallel to each side with joints 8″ from studs staggered 24″ each side attached to studs with 1-5/8″ Type S drywall screws 24″ o.c. and to base layer with 1-1/2″ Type G drywall screws 12″ o.c. spaced 1-1/2″ from vertical edges. Face Layer: 1/2″ ToughRock Fireguard Type C gypsum board applied at right angles to each side joints offset 24″ and attached to studs with 2″ Type S drywall screws 12″ o.c. and with 1-1/2″ Type G drywall screws 24″ o.c. and 1-1/2″ from horizontal joints at midpoint between studs. Sound tested with 1-1/2″ fiberglass insulation.
4-Hour Fire Rating Test Reference: WHI-495-0786 & 0787 	**55-59 STC Sound Trans.** Test Reference: WEAL 87-119 Partition Thickness: 5-5/8″, Weight per Sq. Ft.: 18.0 Base Layer: 1/2″ ToughRock Fireguard Type C gypsum board applied parallel to each side of 1-5/8″ metal studs 24″ o.c. with joints staggered 24″ each side using 1″ Type S drywall screws 12″ o.c. Second Layer: 1/2″ ToughRock Fireguard Type C gypsum board applied parallel to each side with joints staggered 24″ each side attached to studs with 1-5/8″ Type S drywall screws 12″ o.c. Third Layer: 1/2″ ToughRock Fireguard Type C gypsum board applied parallel to each side with joints offset 8″ from studs and staggered 24″ each side, attached to studs with 2″ Type S drywall screws 24″ o.c. and with 1-1/2″ Type G drywall screws 12″ o.c. between studs 1-1/2″ from joints. Face Layer: 1/2″ ToughRock Fireguard Type C gypsum board installed at right angles on each side with joints staggered 24″ o.c. Install 2-1/2″ Type S drywall screws 12″ o.c. to studs and track and 1-1/2″ Type G drywall screws 24″ o.c. and 1-1/2″ from horizontal joints at midpoint between framing. Sound tested with 1-1/2″ fiberglass insulation.

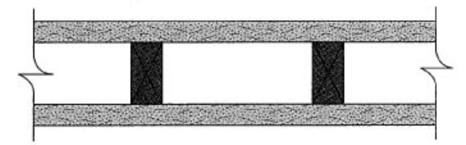
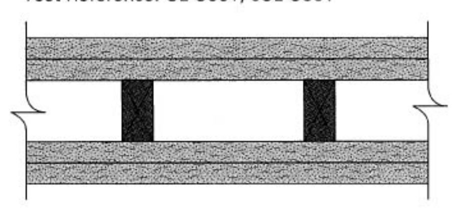
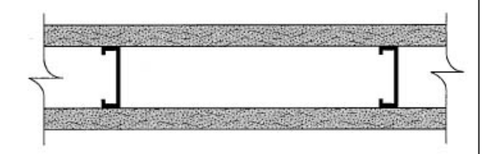
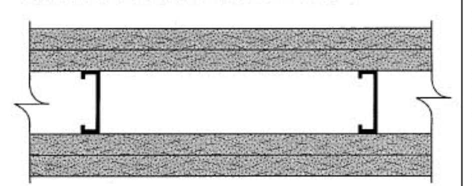
4.6.1.1 High Performance—Sound- and Fire-Rated Interior Assemblies

DensArmor Plus® High-Performance Interior Panels



Fire and Sound Rated Assemblies

DensArmor Plus® High-Performance Interior Panels are offered in 1/2" Fireguard® Type C and 5/8" Fireguard® Type X core types for use in fire-rated assemblies. These panels can be used in any Georgia-Pacific Gypsum or non-proprietary assembly where Type X gypsum board is required.

1-Hour Fire Rating Test Reference: UL U305, ULC W301, GAWP 3605, cUL U305 	**30-34 STC Sound Trans.** Test Reference: OR 64-8 Partition Thickness: 4-7/8" Weight per Sq. Ft.: 7.0 5/8" DensArmor Plus® (formerly DensArmor Plus Interior Drywall) Fireguard® Type X panel applied parallel or at right angles to each side of 2 x 4 wood studs 16" o.c. with 1-7/8" 6d coated nails spaced 7" o.c. Joints staggered. (UL U309, studs 24" o.c.)
2-Hour Fire Rating Test Reference: UL U301, cUL U301 	**40-44 STC Sound Trans.** Test Reference: NGC-2363 Partition Thickness: 6-1/8" Weight per Sq. Ft.: 12.0 Base Layer: 5/8" DensArmor Plus Fireguard Type X panel applied vertically or at right angles to each side of 2 x 4 wood studs 16" o.c. with 1-7/8" 6d coated nails 6" o.c. Face Layer: 5/8" DensArmor Plus Fireguard Type X panel applied vertically or at right angles to studs over base layer with 2-3/8" 8d coated nails 8" o.c. Stagger joints 16" o.c. each layer and side.
1-Hour Fire Rating Test Reference: UL U465, ULC W415, GA WP 1081 	**48 STC Sound Trans.** Test Reference: RAL TL99-103 Partition Thickness: 4-7/8" Weight per Sq. Ft.: 6.0 5/8" DensArmor Plus Fireguard Type X panel applied vertically (UL U465, ULC W415, GA WP 1081) or horizontally (UL U465) to each side of 3-5/8" steel studs 24" o.c. with 1" Type S drywall screws 8" o.c. at edges and 12" o.c. at intermediate studs. **Sound Tested** with 2-1/2" fiberglass insulation, friction fit in cavity
1-Hour Fire Rating Test Reference: UL V450 	Partition Thickness: 2-7/8" Weight per Sq. Ft.: 5.0 5/8" DensArmor Plus Fireguard Type X gypsum board applied vertically to each side of 1-5/8" UltraSTEEL® studs 24" o.c. with 1" Type S drywall screws, 8" o.c. at edges and 12" o.c. at intermediate studs.
2-Hour Fire Rating Test Reference: UL U411, cUL U411 	**50-54 STC Sound Trans.** Test Reference: WHI 218-1 Partition Thickness: 5-1/8" Weight per Sq. Ft.: 10 Base Layer: 5/8" DensArmor Plus Fireguard Type X panel applied parallel to each side of 2-1/2" steel studs 24" o.c. with 1-1/4" Type S screws 16" o.c. Face Layer: 5/8" DensArmor Plus Fireguard Type X panel applied parallel to each side with drywall adhesive or secured with 1-5/8" Type S screws 12" o.c. at top and bottom track, 16" o.c. at edge joints only. Stagger joints 24" each layer and side. **Sound Tested** with 2-1/2" fiberglass insulation

By permission, Georgia-Pacific LLC, Atlanta, Georgia.

4.6.1.1 High Performance—Sound- and Fire-Rated Interior Assemblies (Continued)



DensArmor Plus® High-Performance Interior Panels

2-Hour Fire Rating Test Reference: UL U412, ULC W414 	**50-54 STC Sound Trans.** Test Reference: NRCC 798-NV Partition Thickness: 4-1/2″, Weight per Sq. Ft.: 9.0 **Sound Tested** with 2-1/2″ fiberglass insulation stapled in stud space Base Layer: 1/2″ DensArmor Plus® (formerly DensArmor Plus® Interior Drywall) Fireguard Type C panel applied parallel to each side of 1-5/8″ steel studs 24″ o.c. with 1″ Type S drywall screws 24″ o.c. Face Layer: 1/2″ DensArmor Plus Fireguard Type C panel applied parallel to each side with 1-5/8″ Type S drywall screws 12″ o.c. Joints staggered 24″ each layer and side.
2-Hour Fire Rating Test Reference: V450 	Partition Thickness: 48-1/8″ Weight per Sq. Ft.: 10′ Base Layer: 5/8″ DensArmor Plus Fireguard Type X panel applied at right angles to each side of 1-5/8″ ULTRASteel® studs 24″ o.c. with 1″ Type S screws 24″ o.c. with the first screw installed 1-1/4″ from board edge and to the track. Face Layer: 5/8″ DensArmor Plus Fireguard Type X panel applied at right angles to each side with 1-5/8″ Type S screws spaced 16″ o.c. with the first and second screws installed 1-1/4″ and 8″ from board edge, respectively and to track spaced 16″ o.c. Horizontal joints on face layer staggered 12″ from base layer.

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4.6.2 Abuse-Resistant and Impact-Resistant Fire- and Sound-Rated Assemblies

DensArmor Plus® Abuse-Resistant and Impact-Resistant Panels

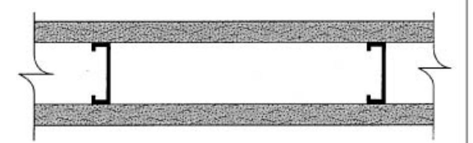


Fire and Sound Rated Assemblies

Like DensArmor Plus® High-Performance Interior Panels, DensArmor Plus® Abuse-Resistant and Impact-Resistant Panels are offered in 5/8″ Type X core types for use in fire-rated assemblies. These panels can be used in any Georgia-Pacific Gypsum or non-proprietary assembly where Type X gypsum board is required.

1-Hour Fire Rating

Test Reference: UL U465, ULC W415, GA WP 1081



48 STC Sound Trans.

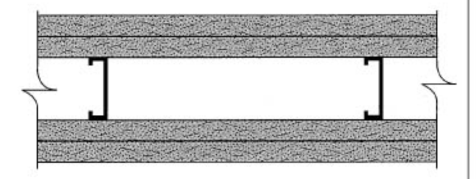
Test Reference: RAL TL99-103
Partition Thickness: 4-7/8″
Weight per Sq. Ft.: 6.0

Any 5/8″ DensArmor Plus® Fireguard® Type X Interior panel applied vertically (U465, W415, WP1081) or horizontally (U465) to each side of 3-5/8″ steel studs 24″ o.c. with 1″ Type S drywall screws 8″ o.c. at edges and 12″ o.c. at intermediate studs.

Sound Tested with 2-1/2″ fiberglass insulation, friction fit in cavity

2-Hour Fire Rating

Test Reference: UL U411, cUL U411



50-54 STC Sound Trans.

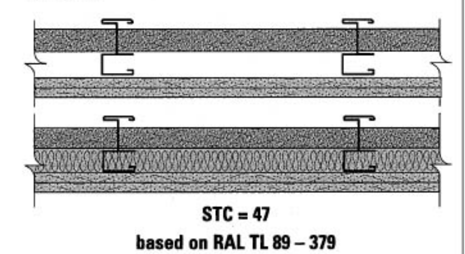
Test Reference: WHI 218-1
Partition Thickness: 5-1/8″
Weight per Sq. Ft.: 10

Base Layer: Any 5/8″ DensArmor Plus Fireguard Type X Interior panel applied parallel to each side of 2-1/2″ steel studs 24″ o.c. with 1-1/4″ Type S screws 16″ o.c.

Face Layer: Any 5/8″ DensArmor Plus Fireguard Type X Interior panel applied parallel to each side with drywall adhesive or secured with 1-5/8″ Type S screws 12″ o.c. at top and bottom track, 16″ o.c. at edge joints only. Stagger joints 24″ each layer and side.

Sound Tested with 2-1/2″ fiberglass insulation

UL V473



STC = 47
based on RAL TL 89 – 379

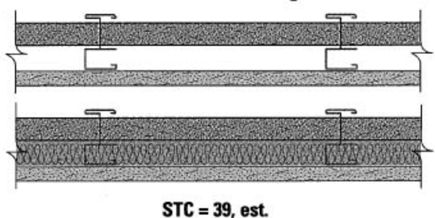
Test Reference: UL V473

Approx. Weight: 9 psf

Fiberglass sound insulation thickness is 1″, 2-1/2″ and 3-1/2″ for C-T and C-H studs of 2-1/2″, 4″ and 6″ respectively. Finished one side. Components: 1″ DensGlass™ Fireguard® Type X Ultra Shaftliner panel, C-T studs and two layers of any 5/8″ DensArmor Plus Fireguard® Type X panels installed horizontally for base layer and vertically for face layer. Edges and ends offset 24″ o.c.

C-T or C-H Stud	2-1/2″	4″	6″
Wall Thickness	3-3/4″	5-1/4″	7-1/4″

Series 622 1-Hour Fire Rating



STC = 39, est.

Test Reference: GA File # WP 7001, WHI Design, GP/WA 60-01

Approx. Weight: 7 psf

Fiberglass sound insulation thickness is 1″, 2-1/2″ and 3-1/2″ for C-T, C-H or I studs of 2-1/2″, 4″ and 6″ respectively. Finished one side. Components: 1″ DensGlass Fireguard Type X Ultra Shaftliner panel, studs and one layer of any 5/8″ DensArmor Plus Fireguard Type X gypsum board installed vertically.

C-T, C-H or I Stud	2-1/2″	4″	6″
Wall Thickness	3-1/8″	4-5/8″	6-5/8″

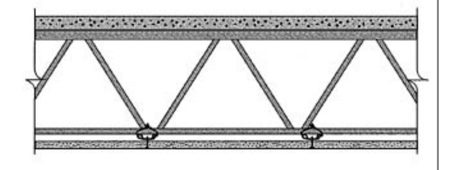
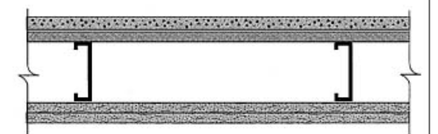
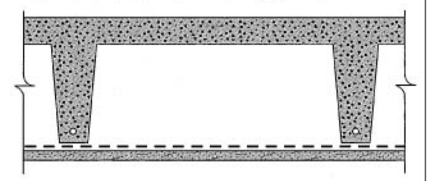
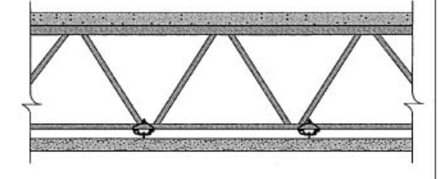
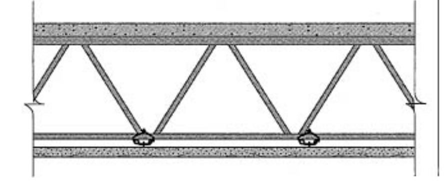
By permission, Georgia-Pacific LLC, Atlanta, Georgia.

4.6.3 Floor/Ceiling Steel Framed Assemblies

Architectural Assemblies



Floor/Ceiling Steel-Framed Assemblies

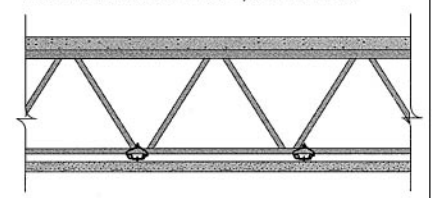
1-1/2-Hour Fire Rating Test Reference: UL G502, ULC I510, GA FC 1110 	Weight per Sq. Ft.: 2.0 1/2″ ToughRock® Fireguard® Type C or 1/2″ DensArmor Plus® Fireguard® Type C gypsum board applied at right angles to rigid resilient channels 24″ o.c. with 1″ Type S screws 12″ o.c. in field. Drywall end joints located midway between continuous channels and attached to additional pieces of channel 52″ long with screws 8″ o.c. Furring channels wire tied to open web steel joists 24″ o.c supporting 3/8″ rib steel lath or 9/16″ deep 28-gauge corrugated steel and 2″ concrete slab measured from top of flute. (Passed 90-minute fire test restrained and unrestrained.)
2-Hour Fire Rating Test Reference: FM FC 224-2, GA FC 2116 	Weight per Sq. Ft.: 5.0 Base Layer: 5/8″ ToughRock Fireguard Type X gypsum board applied at right angles to channel, minimum 7-1/4″ deep, 18-gauge galvanized steel joists 24″ o.c. with 1″ Type S-12 drywall screws 12″ o.c. End joints located midway between joists and staggered between rows. Face Layer: 5/8″ ToughRock Fireguard Type X gypsum board applied at right angles to joists with 1-7/8″ Type S-12 drywall screws 12″ o.c. placed 2″ from edges and 1-1/2″ Type G drywall screws 12″ o.c. placed 2″ back on either side of end joints. End joints located midway between joists and all joints offset 24″ from base layer joints. Joists supporting 28-gauge corrugated steel deck and 2-1/2″ concrete slab measured from the bottom of the flutes. Joists braced at midspan with continuous 2″ wide, 18-gauge, galvanized steel straps attached to the bottom flange of each joist with one 3/8″ Type S-12 panhead screw.
2-Hour Fire Rating Test Reference: PCA 1281-1, GA FC 2120 	Weight per Sq. Ft.: 3.0 5/8″ ToughRock Fireguard Type X gypsum board applied at right angles to resilient channels 24″ o.c. with 1″ Type S drywall screws 8″ o.c. Gypsum board end joints located over continuous channels and attached to additional pieces of channel 54″ long located midway between continuous channels at end joints. Resilient channels 24″ o.c. suspended from 2-1/2″ precast reinforced concrete joists 35″ o.c. with 21-gauge galvanized steel hanger straps fastened to sides of joists. Joist leg depth, 10″.
2-Hour Fire Rating Test Reference: UL G505, ULC I512, GA FC 2130 	Weight per Sq. Ft.: 2.5 5/8″ ToughRock Fireguard Type C gypsum board applied at right angles to rigid furring channels 24″ o.c. with 1″ Type S drywall screws 12″ o.c. Drywall end joints located midway between continuous channels and attached to additional pieces of channel 62″ long with screws 12″ o.c. Furring channels attached with 18-gauge wire ties to open web steel joists 24″ o.c. supporting 3/8″ rib steel lath and 2″ concrete slab. (Two hours restrained and unrestrained.)
2-Hour Fire Rating Test Reference: UL G504, ULC I507 	Weight per Sq. Ft.: 2.0 1/2″ ToughRock Fireguard Type C or 1/2″ DensArmor Plus Fireguard Type C gypsum board applied at right angles to resilient channels 24″ o.c. with 1″ Type S drywall screws 12″ o.c. in field. Drywall end joints located midway between continuous channels and attached to additional pieces of channel 54″ long with screws 8″ o.c. Resilient channels wire tied 24″ o.c. to open web steel joists supporting 3/8″ rib steel lath or 9/16″ deep 28-gauge corrugated steel and 2-1/2″ concrete slab measured from top of flute.

4.6.3 Floor/Ceiling Steel Framed Assemblies (Continued)

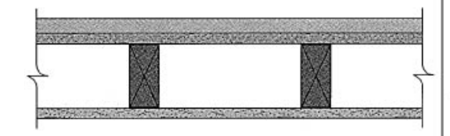
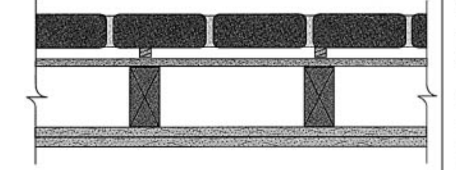


Architectural Assemblies

Floor/Ceiling Steel-Framed Assemblies continued

2-Hour Fire Rating Test Reference: ULC I511, GA FC 2030 	**50-54 STC Sound Trans.** Test Reference: NGC 4075 Weight per Sq. Ft.: 2.0 1/2″ ToughRock® Fireguard® Type C or 1/2″ DensArmor Plus® Fireguard® Type C gypsum board applied at right angles to rigid furring channel 24″ o.c. with 1″ Type S drywall screws 12″ o.c. Gypsum board end joints located midway between continuous channels and attached to additional pieces of channel 54″ long with screws at 12″ o.c. Furring channels 24″ o.c. attached with 18-gauge wire tied 48″ o.c. to open web steel joists 24″ o.c. supporting 9/16″ deep 28-gauge corrugated steel and 2-1/2″ concrete slab. Furring channels may be attached to 1-1/2″ cold rolled channels 48″ o.c. suspended from joists by 8-gauge wire hangers not more than 48″ o.c. (Two hour restrained and unrestrained.)

Exterior Wood-Framed Wall Assemblies

1-Hour Fire Rating Test Reference: UL U305, cUL U305, ULC W 301 	Partition Thickness: 4-3/4, Weight per Sq. Ft.: 7.5 Exterior Side: 5/8″ DensGlass™ Fireguard® Type X Exterior Sheathing (formerly DensGlass Gold® Exterior Sheathing) applied parallel or at right angles to 2 x 4 wood studs 16″ o.c. with 1-3/4″ galvanized roofing nails 7″ o.c. Exterior surface covered with weather exposed cladding or finish system. Interior Side: One layer 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to studs with 1-7/8″ 6d coated 7″ o.c. Stagger joints each side.
1-Hour Fire Rating Test Reference: UL U309, GA WP 8109, cUL U309 	Partition Thickness: Varies, Weight per Sq. Ft.: 9.0 Exterior Side: 5/8″ DensGlass Fireguard Type X Exterior Sheathing applied parallel or at right angles to 2 x 4 wood studs 24″ o.c. with 1-7/8″ galvanized roofing nails 7″ o.c. Joints of gypsum sheathing may be left untreated. Exterior cladding to be attached through sheathing to studs. Interior Side: 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to studs with 1-7/8″ 6d coated nails 7″ o.c.
2-Hour Fire Rating Test Reference: UL U302, ULC U302, GA WP 8410 	Wall Thickness: 10-1/8 Interior Base Layer: 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to 2 x 4 wood studs 16″ o.c. with 1-7/8″ 6d coated nails 8″ o.c. Face Layer: 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board applied parallel or at right angles to studs with 2-3/8″ 8d coated nails 8″ o.c. Exterior Base Layer: 1/2″ DensGlass™ Exterior Sheathing (formerly DensGlass Gold® Exterior Sheathing) applied parallel or at right angles to studs with 1-3/4″ galvanized roofing nails 6″ o.c. Face Layer: 2″ x 4″ x 8″ clay brick with 1″ air space between brick and exterior sheathing. 20-gauge galvanized wire ties attached to each stud with 2-3/8″ 8d coated nails, located at every sixth course of bricks.

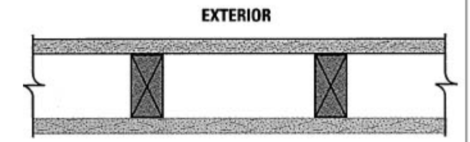
4.6.4 Fire-Rated Exterior Wood—Steel Framing Assemblies



DensGlass™ Exterior Sheathing

Fire-Rated Assemblies (Wood-Framed)[1]

1-Hour Fire Rating



Test Reference: UL U337, U305, WHI 495-0702, ULC W301, GA WP 5515

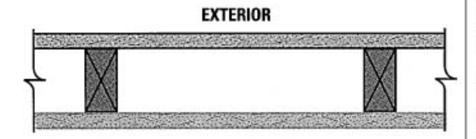
Wall Thickness: 4-7/8″

Weight per Sq. Ft.: 7.5

Exterior: 5/8″ DensGlass™ Fireguard® Type X Exterior Sheathing (formerly DensGlass Gold® Exterior Sheathing) applied parallel (U337, W301, U305) or at right angles (U305) to 2 x 4 wood studs 16″ o.c. with 1-3/4″ galvanized roofing nails 7″ o.c. for all framing members. Exterior surface covered with weather exposed cladding or finish system.

Interior: 5/8″ DensArmor Plus® Fireguard® Type X interior panels or 5/8″ ToughRock® Fireguard® Type X gypsum board applied parallel or at right angles to studs with 1-7/8″ 6d coated nails 7″ o.c. Stagger joints each side. **(Load-bearing)**

1-Hour Fire Rating



Test Reference: UL U309, cUL U309

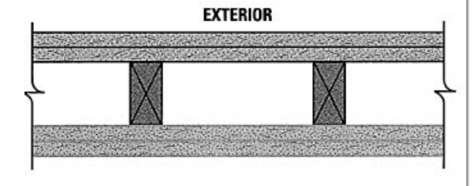
Wall Thickness: 4-7/8″

Weight per Sq. Ft.: 7.5

Exterior: 5/8″ DensGlass Fireguard Type X Exterior Sheathing applied parallel or at right angles to 2 x 4 wood studs spaced 24″ o.c. with 1-7/8″ galvanized roofing nails 7″ o.c.

Interior: 5/8″ DensArmor Plus Fireguard Type X or 5/8″ ToughRock Fireguard Type X gypsum board to framing with 1-7/8″ 6d coated nails 7″ o.c. **(Load-bearing)**

2-Hour Fire Rating



Test Reference: UL U301, cUL U301

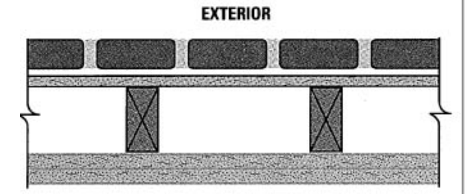
Wall Thickness: 6-1/8″

Weight per Sq. Ft.: 12.5

Exterior: Two layers 5/8″ DensGlass Fireguard Type X Exterior Sheathing applied parallel or at right angles to 2 x 4 wood studs 16″ o.c. Base layer attached with 1-7/8″ galvanized roofing nails 16″ o.c. Face layer attached with 2-3/8″ galvanized roofing nails 8″ o.c. Stagger joints between layers and on base layer of both sides.

Interior: Two layers 5/8″ DensArmor Plus Fireguard Type X or 5/8″ ToughRock Fireguard gypsum board applied horizontally or vertically to framing. Base layer attached with 1-7/8″ 6d cement coated nails 6″ o.c. Face layer attached with 2-3/8″ 6d cement coated nails 8″ o.c. Stagger joints between layers and on base layer of both sides. **(Load-bearing)**

2-Hour Fire Rating



Test Reference: UL U302, cUL U302, GA WP8410

Wall Thickness: 10-1/8″

Exterior: One layer 1/2″ DensGlass Exterior Sheathing applied parallel or at right angles to studs with 1-3/4″ galvanized roofing nails 6″ o.c. Face layer is 2″ x 4″ x 8″ clay brick with 1″ air space between brick and exterior sheathing. 20-gauge galvanized wire ties attached to each stud with 8d coated nails as described above, located at every sixth course of bricks. **(Load-bearing)**

Interior: Two layers 5/8″ DensArmor Plus Fireguard Type X or 5/8″ ToughRock Fireguard Type X gypsum board applied parallel or at right angles to 2 x 4 wood studs 16″ o.c. Base layer attached with 1-7/8″ 6d coated nails 8″ o.c. Face layer attached with 2-3/8″ coated nails 8″ o.c.

[1]Load restricted for Canadian applications—see UL Guide BXUV7.

By permission, Georgia-Pacific LLC, Atlanta, Georgia.

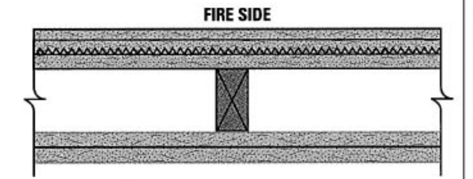
4.6.4 Fire-Rated Exterior Wood—Steel Framing Assemblies (Continued)

DensGlass™ Exterior Sheathing



Fire-Rated Assemblies (Wood-Framed)[1]

2-Hour Fire Rating



Test Reference: ULC 12-21-67, GA WP8420

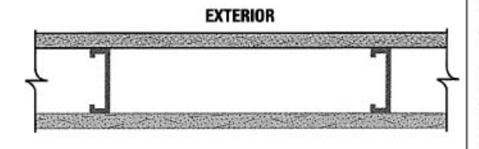
Wall Thickness: 8-5/8″

Exterior: Base layer 5/8″ DensGlass™ (formerly DensGlass Gold® Exterior Sheathing) Fireguard® Type X Exterior Sheathing retardant treated 2 x 6 wood studs 16″ o.c. with 6d coated nails, 1-7/8″ long, 0.0915″ shank, 1/4″ heads, 12″ o.c. and covered with a single layer fire resistant protective weather retarder paper stapled along each edge at 16″ o.c. Galvanized self-furring wire mesh applied over sheathing with 8d galvanized roofing nails, 2-3/8″ long, 0.113″ shank, 9/32″ heads, 6″ o.c. Cement-stucco applied over wire mesh in two 1/2″ thick coats with bonding agent applied between coats.

Interior: Base layer 5/8″ DensArmor Plus® Fireguard Type X or 5/8″ ToughRock® Fireguard® Type X applied parallel to studs with 6d coated nails, 1-7/8″ long, 0.0915″ shank, 1/4″ heads, 12″ o.c. Face layer 5/8″ DensArmor Plus Fireguard Type X or 5/8″ ToughRock® Fireguard® Type X applied at right angles to studs with 8d coated nails, 2-3/8″ long, 0.113″ shank, 9/32″ heads, 8″ o.c. at edges and 12″ o.c. at intermediate studs. **(Load-bearing)**

Fire-Rated Assemblies (Steel-Framed)

1-Hour Fire Rating



Test Reference: UL U465, ULC W 415, cUL U465, GA WP1081

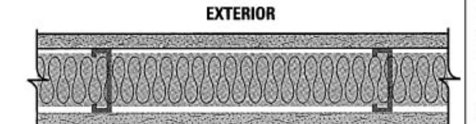
Wall Thickness: 4-7/8″

Weight per Sq. Ft.: 6 psf

Exterior: 5/8″ DensGlass Fireguard® Type X Exterior Sheathing applied vertically to min. 3-5/8″ corrosion resistant 25-gauge steel studs 24″ o.c. with 1″ Type S corrosion resistant bugle head screws 8″ o.c. at board edges and 8″ at intermediate studs.

Interior: 5/8″ DensArmor Plus Fireguard® Type X or 5/8″ ToughRock® Fireguard® Type X gypsum board applied vertically to framing with 1″ Type S bugle head screws 8″ o.c. at board edges and 12″ at intermediate studs.

1-Hour Fire Rating



Test Reference: UL U425,[1] cUL U425

Wall Thickness: 4-3/4″

Weight per Sq. Ft.: 6 psf

Exterior: 5/8″ DensGlass Exterior Sheathing applied vertically to min. 3-1/2″ corrosion resistant 20-gauge steel studs 24″ o.c. with 1″ Type S corrosion resistant bugle head screws 8″ o.c.

Interior: 5/8″ DensArmor Plus Fireguard Type X or 5/8″ ToughRock Fireguard Type X gypsum board applied vertically to framing with 1″ Type S bugle head screws 12″ o.c. Insulation to completely fill stud cavity. **(Load-bearing: 100% of design load)**

[1]Load restricted for Canadian applications—see UL Guide BXUV7.

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4.6.5 Steel Column, Beam—Fire-Resistant and Abuse-Resistant Assemblies

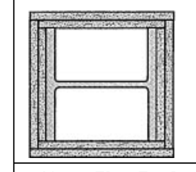
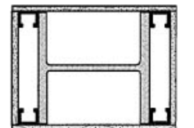
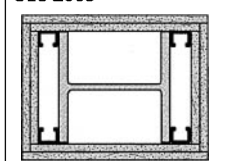
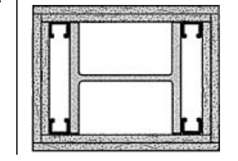


Architectural Assemblies

Column Fire-Resistant Assemblies

ToughRock gypsum board provides a fast, efficient and economical method of protecting steel columns. Fire-resistant assemblies with two-, three- and four-hour ratings are obtainable for heavyweight columns, and a four-hour rating for lightweight columns, depending upon the number of layers of 5/8″ ToughRock® Fireguard® Type X or 1/2″ ToughRock Fireguard Type C gypsum board used. These layers are held in place by a combination of screws and steel studs.

- Fire Resistant – For three-hour fire rating, two layers of 1/2″ ToughRock Fireguard Type C gypsum board can be used. Design No. X513 3-hour. Two-hour fire rating can be obtained using one layer of 1/2″ ToughRock Fireguard Type C gypsum board. Design No. X520 2-hour. These are for heavyweight columns (14 WF 228).
- Lighter – Compared to other types of column fire-resistant assemblies, a dead-load savings from 50% to 75% can be realized with ToughRock gypsum board.
- Faster to Erect – ToughRock gypsum board can be installed quickly and easily when used for column fire proofing following Georgia-Pacific Gypsum details. Minimum amount of wire and adhesives are used.

1-Hour Fire Rating Test Reference: NBS 303 	Base Layer: 1/2″ ToughRock® gypsum board tied to W10 x 49 column 1 hr. with 18-gauge wire 15″ o.c. Face Layer: 1/2″ ToughRock gypsum board applied with laminating compound over entire contact surface.
2-Hour Fire Rating Test Reference: UL X520, GA CM 2110, cUL X520 	1/2″ ToughRock Fireguard Type C or 1/2″ DensArmor Plus® Fireguard Type C gypsum board attached to 1-5/8″ steel studs with 1″ Type S drywall screws 12″ o.c. Studs located at each corner of heavy steel W14 x 288 column. 1-1/4″ steel corner bead crimp-attached at 6″ intervals.
2-Hour Fire Rating Test Reference: UL X517, ULC Z503 	Two layers of 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus® Fireguard Type X gypsum board screw-attached to 1-5/8″ steel studs located at each corner of W10 x 49 column with 1″ Type S screws 24″ o.c. for base layer and 1-5/8″ Type S drywall screws 12″ o.c. for face layer. 1-1/4″ steel beads at corners attached with 6d coated nails 1-3/4″ long, 0.0915″ shank, 1/4″ heads, 12″ o.c.
3-Hour Fire Rating Test Reference: UL X513, GA CM 3130, cUL X513 	Two layers of 1/2″ ToughRock Fireguard Type C gypsum board or 1/2″ DensArmor Plus Fireguard Type C. Base Layer: Screw-attached to 1-5/8″ steel studs located at corners of heavy steel W14 x 228 column with 1″ Type S screws 24″ o.c. Face Layer: Attached with 1-5/8″ Type S drywall screws 12″ o.c. into studs. 1″ corner bead applied each corner with 1-3/8″ 4d coated nails 12″ o.c.

Abbreviations

ACI	Acoustical Consultants Inc.
CK	Cedar Knolls Acoustical Laboratories (Noise Unlimited, Inc.)
cUL	Underwriters Laboratories Inc. (Canadian Listed)
DRC	Domtar Research Centre
FM	Factory Mutual Research Corporation
GA	Gypsum Association
G&H	Geiger and Hamme
IIC	Impact Insulation Class
KAL	Kodaras Acoustical Laboratories
NBS	National Bureau of Standards
NGC	NGC Testing Services
NRCC	National Research Council of Canada
OR	Ohio Research Corporation
OSU	Ohio State University
PCA	Portland Cement Association
RAL	Riverbank Acoustical Laboratories
STC	Sound Transmission Class
SWRI	Southwest Research Institute
UC	University of California
UL	Underwriters Laboratories Inc.
ULC	Underwriters' Laboratories of Canada
WEAL	Western Electro Acoustical Laboratory, Inc.
WHI	Warnock Hersey International (ITS)

COMMONLY USED METRIC CONVERSIONS

Gypsum Panel Thickness
1/4 in. – 6.4 mm
1/2 in. – 12.7 mm
5/8 in. – 15.9 mm
1 in. – 25.4 mm

Gypsum Panel Width
2 ft. – 610 mm
4 ft. – 1219 mm
32 in. – 813 mm

Gypsum Panel Length
4 ft. – 1219 mm
5 ft. – 1524 mm
8 ft. – 2438 mm
9 ft. – 2743 mm
10 ft. – 3048 mm
12 ft. – 3658 mm

Framing Spacing
16 in. – 406 mm
24 in. – 610 mm

Fastener Spacing
2 in. – 51 mm
2.5 in. – 64 mm
7 in. – 178 mm
8 in. – 203 mm
12 in. – 305 mm
16 in. – 406 mm
24 in. – 610 mm

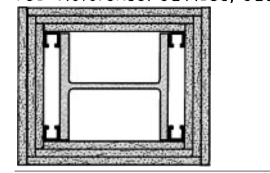
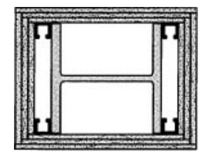
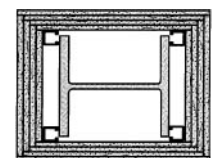
Temperature
40°F – 5°C
50°F – 10°C
125°F – 52°C

4.6.5 Steel Column, Beam—Fire-Resistant and Abuse-Resistant Assemblies (Continued)

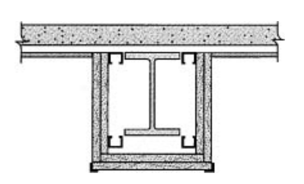
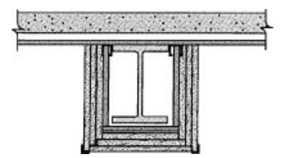
Architectural Assemblies



Column Fire Protection Assemblies continued

3-Hour Fire Rating Test Reference: UL X509, ULC Z502 	Three layers of 5/8″ ToughRock® Fireguard® Type C gypsum board, screw-attached to 1-5/8″ steel studs located at each corner of W10 x 49 column. Base Layer: Attached with 1″ Type S drywall screws 24″ o.c. Second Layer: Attached with 1-5/8″ Type S drywall screws 12″ o.c. and 18-gauge wire tied 24″ o.c. Face Layer: Attached with 2-1/4″ Type S drywall screws 12″ o.c. and 1-1/4″ corner bead at each corner nailed with 1-7/8″ 6d coated nails 12″ o.c.
3-Hour Fire Rating Test Reference: UL X528, cUL X528 	Three layers of 1/2″ ToughRock Fireguard Type C or 1/2″ DensArmor Plus® Fireguard® Type C gypsum board, screw-attached to 1-5/8″ steel studs located at each corner of W10 x 49 column. Base Layer: Attached with 1″ Type S drywall screws 24″ o.c. Second Layer: Attached with 1-5/8″ Type S drywall screws 24″ o.c. Face Layer: Attached with 2-1/4″ Type S drywall screws 12″ o.c. and 1-1/4″ corner bead at each corner nailed with 4d coated nails. Joint compound 1/16″ thick applied over corner bead and entire outer layer of drywall.
4-Hour Fire Rating Test Reference: UL X501, cUL X501 	Four layers of 5/8″ ToughRock Fireguard Type C gypsum board covering W10 x 49 steel column. Inner Layer: Attached to steel studs with 1″ long self-drilling, self-tapping screws spaced vertically 24″ o.c. Second Layer: Attached to steel studs with 1-5/8″ long self-drilling, self-tapping screws spaced vertically 24″ o.c. Third Layer: Attached to sheet-metal angles with 1″ long, self-drilling, self-tapping screws spaced vertically 12″ o.c. Outer Layer: Gypsum board attached to the sheet metal angles with 1-5/8″ long self-drilling, self-tapping screws spaced vertically 12″ o.c.

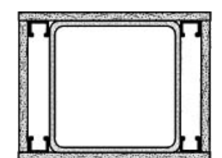
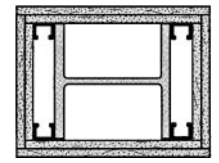
Beam Fire-Resistant Assemblies

2-Hour Fire Rating Test Reference: UL, N502, ULC 0502, GA BM 2130 	Two layers of 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board around beam. Base Layer: Attached with 1-1/4″ Type S drywall screws 16″ o.c. Face Layer: Attached with 1-3/4″ Type S drywall screws 8″ o.c to horizontally installed U-shaped steel channels (25-gauge steel 11-1/16″ wide with 1″ legs) located not less than 1/2″ from beam flanges. Upper channels secured to steel deck units with 1/2″ Type S pan-head screws spaced 12″ o.c. U-shaped brackets formed of steel channels spaced 24″ o.c. suspended from the upper channels with 1/2″ Type S pan-head screws and supported steel channels installed at lower corners of brackets. Outside corners of gypsum board protected by 0.020″ thick steel corner beads crimped or nailed. (Two-hour restrained or unrestrained beam.)
3-Hour Fire Rating **Restrained Beam** **2-Hour Fire Rating** **Unrestrained Beam** Test Reference: UL N505 	Three layers of 5/8″ ToughRock Fireguard Type X or 5/8″ DensArmor Plus Fireguard Type X gypsum board around minimum W 8 x 24 beam. Base Layer: Attached with 1″ Type S drywall screws 16″ o.c. Middle Layer: Attached with 1-5/8″ Type S drywall screws 12″ o.c. Face Layer: Attached with 2-1/4″ Type S drywall screws 5/8″ o.c. to horizontally installed steel channels (25-gauge steel 11-1/16″ wide with 1″ legs) located not less than 1/2″ from beam flanges. Upper channels secured to steel deck units with 1/2″ Type S pan-head screws spaced 12″ o.c. Brackets formed of steel channels spaced 24″ o.c. suspended from the upper channels with 1/2″ Type S pan-head screws and supported steel channels installed at lower corners of brackets. 20-gauge hexagonal steel mesh fitted between middle and face layers of gypsum board along bottom and extending 1-1/2″ onto sides. Outside corners of gypsum board protected by steel corner beads crimped or nailed to the gypsum board. 1-1/2″ fluted steel deck units welded to top of beam and supporting minimum 2-1/2″ concrete. (Three-hour restrained or two-hour unrestrained beam.)

4.6.5 Steel Column, Beam—Fire-Resistant and Abuse-Resistant Assemblies (Continued)



DensArmor Plus® Abuse-Resistant and Impact-Resistant Panels

1-Hour Fire Rating Test Reference: UL X528, GA CM 1851 	One layer of any 5/8″ DensArmor Plus® Fireguard® Type X panel applied without horizontal joints and parallel to 1-5/8″ steel studs located at each corner of TS8x8x0.250 tube steel column with 1″ Type S drywall screws 24″ o.c. Steel cornerbead, 1-1/2″ flanges, applied with 1″ Type S drywall screws 12″ o.c. in each flange. Joint compound 1/16″ thick applied over corner bead.
2-Hour Fire Rating Test Reference: UL X517, ULC Z503 	Two layers of any 5/8″ DensArmor Plus Fireguard Type X gypsum board screw-attached to 1-5/8″ steel studs located at each corner of W10 x 49 column with 1″ Type S screws 24″ o.c. for base layer and 1-5/8″ Type S drywall screws 12″ o.c. for face layer. 1-1/4″ steel beads at corners attached with 6d coated nails 1-3/4″ long, 0.0915″ shank, 1/4″ heads, 12″ o.c.

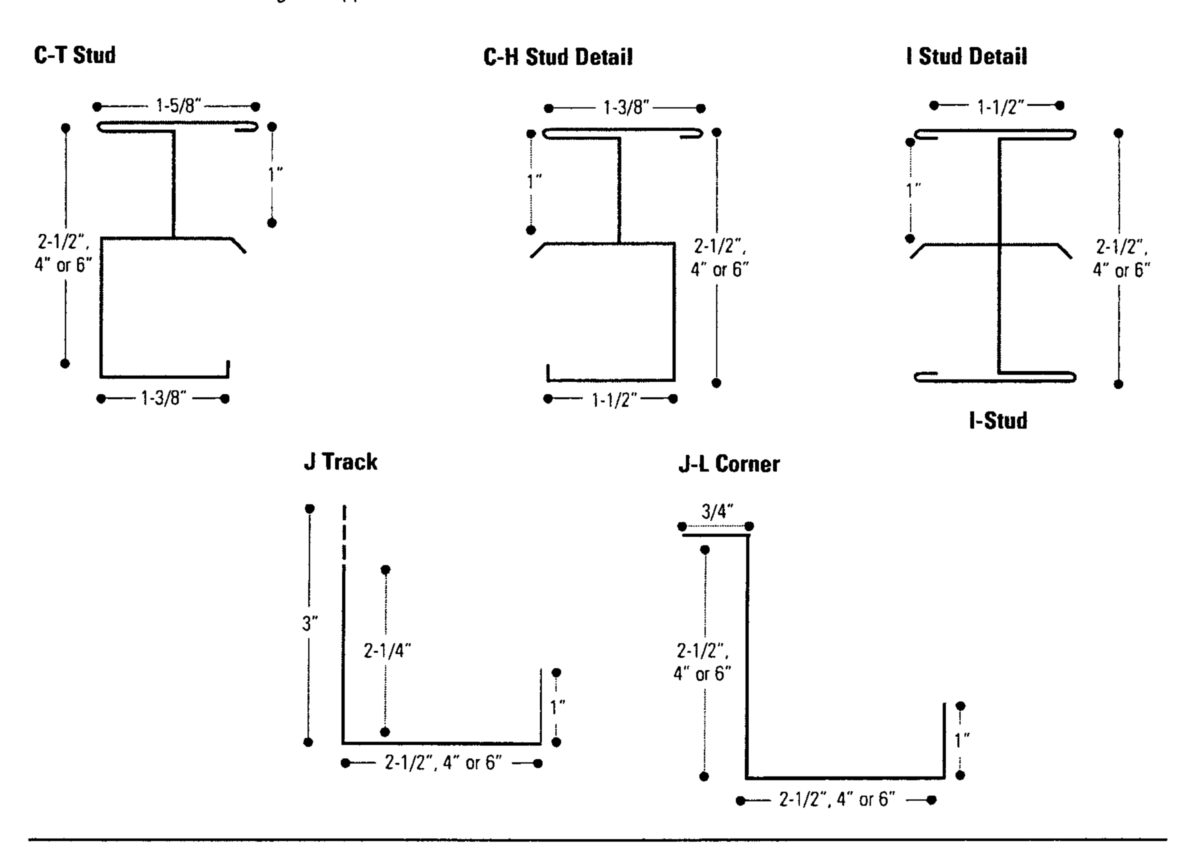
By permission, Georgia-Pacific LLC, Atlanta, Georgia.

4.6.6 Shaft Wall Construction Framing Members

DensGlass™ Ultra Shaftliner Shaftwall/Stairwell Systems



See individual fire test listings for approved studs.



Recommendations

- Use a fastening plate to secure the J track whenever fasteners are closer than 4" to the edge. Setting the plate at the time of concrete construction will avoid spalling by mechanical fasteners.
- Cut C-T, C-H or I studs 3/4" less than the height of the opening.
- Cut 1" DensGlass™ Ultra Shaftliner panel 3/4" less than the height of the opening.
- In structural steel-frame construction, install J track sections before applying spray-on fireproofing.
- Items to be anchored to the wall (cabinets, sinks, handrails, etc.) should be fastened to the C-T, C-H or I studs or to plates secured behind or between layers of 1/2" ToughRock® Fireguard® Type C gypsum board. (See illustration on page 12.)
- Joint compounds should be applied at ambient temperatures above 50°F (10°C) with adequate ventilation.
- Use Type S screws for 25-gauge steel framing. Use Type S-12 screws for 20-gauge (or heavier) steel framing.
- It is important that the job structural engineer approves the type, size and maximum spacing of track fasteners to meet the design load requirements.

4.6.7 Horizontal, Vertical Shaft Wall Assemblies

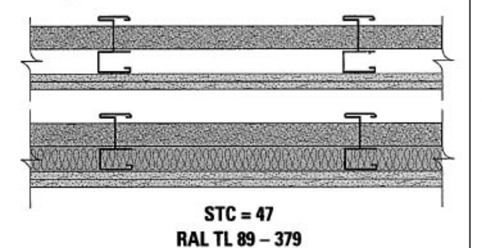


DensArmor Plus® High-Performance Interior Panels

Shaftwall/Stairwell Design Summary Vertical

Series 620 2-Hour Fire Rating

Test Reference: GA File #, WP 7096, WHI Design, GP/WA 120-01



STC = 47
RAL TL 89 – 379

Approx. Weight: 9 psf

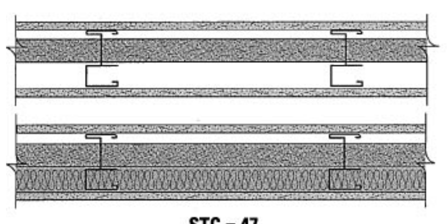
Fiberglass sound insulation thickness is 1", 2-1/2" and 3-1/2" for C-T, C-H or I studs of 2-1/2", 4" and 6" respectively. Finished one side. Components: 1" DensGlass™ Fireguard Type X Ultra Shaftliner (formerly DensGlass Ultra® Shaftliner) panel, C-T studs and two layers of 1/2" DensArmor Plus® Fireguard® Type C installed horizontally or vertically. Edges and ends offset 24" o.c.

C-T, C-H or I Stud	2-1/2"	4"	6"
Wall Thickness	3-1/2"	5"	7"

Sound Tested with 1-1/2" fiberglass insulation, friction fit in cavity

Series 621 2-Hour Fire Rating

Test Reference: WHI Design, GP/WA 120-02, GA File # WP 7097



STC = 47
RAL TL 89 – 380

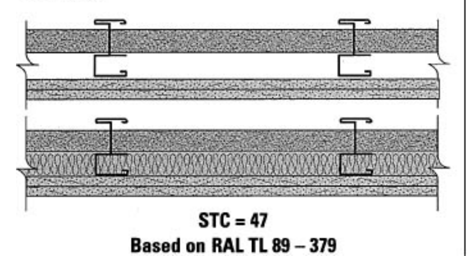
Approx. Weight: 9 psf

Fiberglass sound insulation thickness is 1", 2-1/2" and 3-1/2" for C-T, C-H or I studs of 2-1/2", 4" and 6" respectively. Finished both sides with 1/2" DensArmor Plus Fireguard Type C installed horizontally or vertically. Edges and ends offset 24" o.c.

C-T, C-H or I Stud	2-1/2"	4"	6"
Wall Thickness	3-1/2"	5"	7"

Sound Tested with 1-1/2" fiberglass insulation, friction fit in cavity

UL V473



STC = 47
Based on RAL TL 89 – 379

Test Reference: UL V473

Approx. Weight: 9 psf

Fiberglass sound insulation thickness is 1", 2-1/2" and 3-1/2" for C-T or C-H studs of 2-1/2", 4" and 6" respectively. Finished one side. Components: 1" DensGlass™ Fireguard® Type X Ultra Shaftliner panel, C-T or C-H studs and two layers of 5/8" DensArmor Plus® Fireguard® Type X installed horizontally for base layer and vertically for face layer. Edges and ends offset 24" o.c.

C-T or C-H Stud	2-1/2"	4"	6"
Wall Thickness	3-3/4"	5-1/4"	7-1/4"

By permission, Georgia-Pacific LLC, Atlanta, Georgia.

4.6.7 Horizontal, Vertical Shaft Wall Assemblies (Continued)



Architectural Assemblies

Design Summary Vertical – Shaftwall Assemblies

Series 621 2-Hour Fire Rating

STC = 45 RAL TL 89 – 380

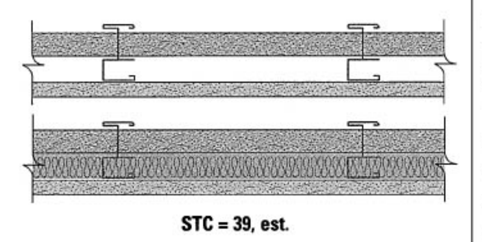
Test Reference: GA File # WP 7073, WHI Design, GP/WA 120-02

Approx. Weight: 9 psf

Fiberglass sound insulation thickness is 1″, 2-1/2″ and 3-1/2″ for C-T, C-H or I studs of 2-1/2″, 4″ and 6″ respectively. Finished both sides with 1/2″ DensArmor Plus® Fireguard Type C or 1/2″ ToughRock® Fireguard® Type C gypsum board installed horizontally or vertically. Edges and ends offset 24″ o.c.

C-T, C-H or I Stud	2-1/2″	4″	6″
Wall Thickness	3-1/2″	5″	7″

Series 622 1-Hour Fire Rating



Test Reference: GA File # WP 7001, WHI Design, GP/WA 60-01

Approx. Weight: 7 psf

Fiberglass sound insulation thickness is 1″, 2-1/2″ and 3-1/2″ for C-T, C-H or I studs of 2-1/2″, 4″ and 6″ respectively. Finished one side. Components: 1″ DensGlass™ Fireguard Type X Ultra Shaftliner panel, studs and one layer of 5/8″ ToughRock Fireguard or 5/8″ DensArmor Plus Fireguard Type X gypsum board installed vertically.

C-T, C-H or I Stud	2-1/2″	4″	6″
Wall Thickness	3-1/8″	4-5/8″	6-5/8″

By permission, Georgia-Pacific LLC, Atlanta, Georgia.

4.6.7 Horizontal, Vertical Shaft Wall Assemblies (Continued)

Architectural Assemblies



Design Summary Horizontal – Shaftwall Assemblies

Series 623 2-Hour Fire Rating	Test Reference: WHI-495-PSH-0128 Approx. Weight: 11 psf Designed for ceiling or duct shaft and composed of 1″ DensGlass™ Fireguard® Type X Ultra Shaftliner (formerly DensGlass Ultra® Shaftliner) panel supported by 2-1/2″, 4″ or 6″ C-T studs and three layers of 1/2″ ToughRock® Fireguard® Type C or 1/2″ DensArmor Plus® Fireguard® Type C gypsum board.
Series 624 2-Hour Fire Rating	Test Reference: WHI-495-PSH-0153 & WHI-495-PSH-0197 Approx. Weight: 11 psf Designed to separate a room from structure or space above and composed of 1″ DensGlass Fireguard Type X Ultra Shaftliner panel supported by 2-1/2″, 4″ or 6″ C-T studs and three layers of 1/2″ ToughRock Fireguard Type C or 1/2″ DensArmor Plus Fireguard Type C gypsum board.
Series 627 2-Hour Fire Rating	Test Reference: WHI-495-PSH-0183 & WHI-495-PSH-0196, WHI Design GP/CC 120-01 Approx. Weight: 11 psf Designed to separate a room from structure or space above and composed of 1″ DensGlass Fireguard Type X Ultra Shaftliner panel supported by 2-1/2″, 4″ or 6″ C-T studs and three layers of 1/2″ ToughRock Fireguard Type C or 1/2″ DensArmor Plus Fireguard Type C gypsum board.

System Assemblies – 2-Hour Ratings – Area Separation Walls

Construction Detail	Assembly Components	STC	Test Reference
	Two layers 1″ DensGlass™ Fireguard® Type X Ultra Shaftliner inserted in H-Studs 24″ o.c. Min. 3/4″ air space between liner panels and adjacent wood or metal framing.	**60**	UL U373 ULC W312 WHI GP/WA 120-03 RAL TL89-383
	Two layers 1″ DensGlass Fireguard Type X Ultra Shaftliner inserted in H-Studs 24″ o.c. Min. 3/4″ air space on both sides must be maintained between liner panels and adjacent framing. **Sound Tested** with 2 x 4 stud wall with 1/2″ DensArmor Plus® interior panels each side of assembly and 3-1/2″ fiberglass insulation in stud space both sides.	**60**	UL U373 ULC W312 WHI GP/WA 120-04 Based on RAL TL89-383
	Part. Thickness: 3″ Weight per Sq. Ft.: 9.5 Two layers 1″ DensGlass Fireguard Type X Ultra Shaftliner inserted in H-Studs 24″ o.c. Metal covered using 6″ wide 1/2″ DensArmor Plus Fireguard® Type C Interior Panel or 1/2″ ToughRock® Fireguard Type C gypsum board.	**38 est.**	WHI 495-0743

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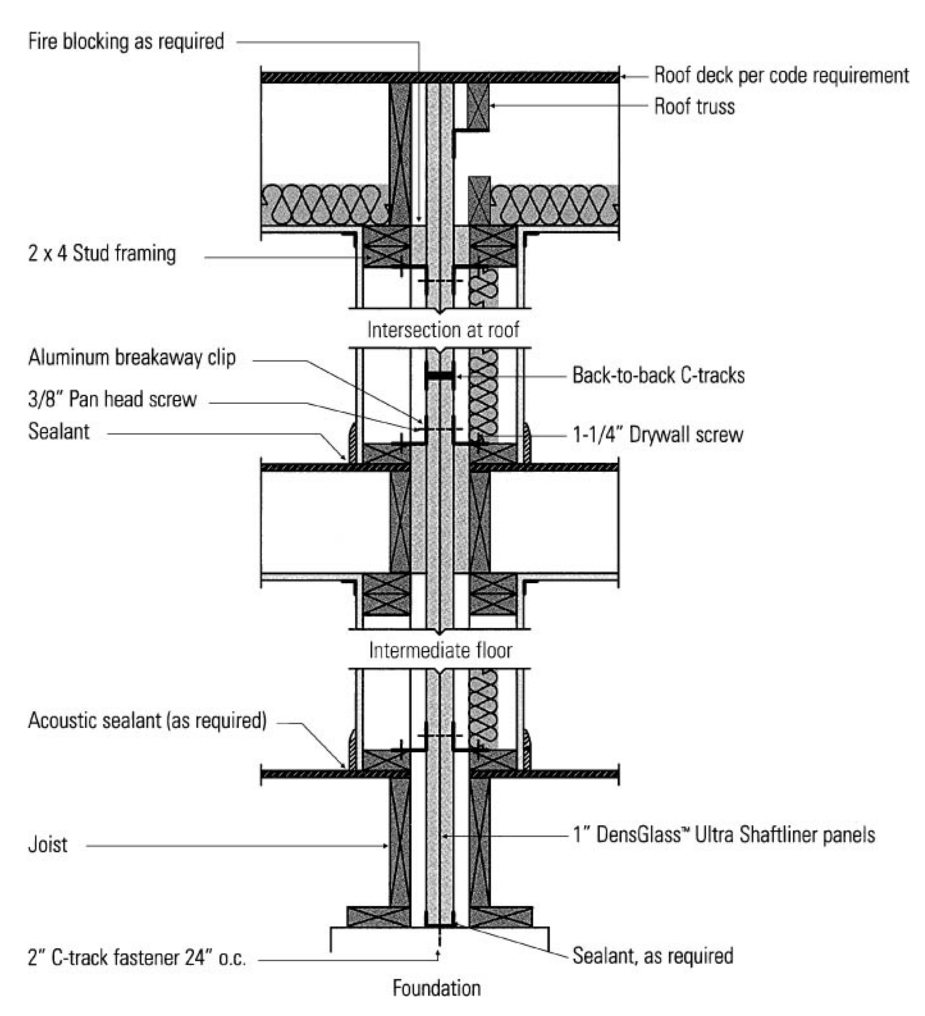
4.6.8 Area Separation Walls



DensGlass™ Ultra Shaftliner Area Separation Walls

Details

Full Wall



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4.6.9 Gypsum Board—Georgia-Pacific Specifications



Product Selection Guide

Dens™ Brand Fiberglass Mat Gypsum Panels

Product	Dimensions			Edge					Standard
DensArmor Plus® High-Performance, and Abuse-Resistant panels are GREENGUARD Children & Schools℠ certified for low VOCs.	TH	W	L	TE	S	RE	B	DB	ASTM
DensArmor Plus® High-Performance Interior Panel – Fiberglass mat gypsum interior panel consisting of moisture-resistant noncombustible* gypsum core with coated fiberglass mat facings front and back. Offers superior resistance to moisture and mold.	1/2″	4′	8′ to 12′	•					C 1658, Applicable Sections of C 630, C 1396 and C 1177
DensArmor Plus® Fireguard® Type X High-Performance Interior Panel – Gypsum panel is UL and ULC classified, has fiberglass mat facings on front and back for superior resistance to moisture and mold.	5/8″	4′	8′ to 12′	•					C 1658, Applicable Sections of C 630, C 1396 and C 1177
DensArmor Plus Fireguard® Type C High-Performance Interior Panel – Noncombustible Fireguard Type C gypsum core with fiberglass mat facings on front and back. Use as described above. Appropriate for commercial applications requiring extended fire resistance ratings and for added protection against mold growth in the wall cavity. UL and ULC Classified.	1/2″	4′	8′ to 12′	•					C 1658, Applicable Sections of C 630, C 1396 and C 1177
DensArmor Plus® Fireguard® Type X Abuse-Resistant Interior Panel – Abuse-resistant paperless drywall panel for high traffic areas. Fiberglass mat and treated core offer superior resistance to moisture and mold. UL Classified.	5/8″	4′	8′ to 12′	•					C 1658, Applicable Sections of C 630, C 1396 and C 1177
DensArmor Plus® Fireguard® Type X Impact-Resistant Interior Panel (formerly DensArmor Plus® High Impact) – Fiberglass mat interior gypsum panel specifically designed to resist high or continual impact and protect the stud cavity. Specially formulated core provides greater resistance to surface indentation and abuse. UL Classified.	5/8″	4′	8′ to 12′	•					C 1658, Applicable Sections, of C 630, C 1396 and C 1629
DensShield® Tile Backer – Tile backer board for installing tile on interior walls, ceilings, floors and countertops. Superior moisture protection for permanent tile installations. Easily installed, light-weight and outperforms cement board.	1/4″ 1/2″ 1/2″ 1/2″	4′ 32″ 4′ 4′	4′ 5′ 8′ 5′		• • • •				C 1178
DensShield® Fireguard® Type X Tile Backer – Use as described above. Patented tile backer with noncombustible core. Can be used in fire-rated assemblies. UL and ULC Classified.	5/8″	4′	8′		•				C 1178
DensDeck® Roof Board – Superior, nonstructural thermal barrier roof board for commercial roof and re-roof applications. Fiberglass mat facings with water-resistant treated core.	1/4″ 1/2″ 1/2″	4′ 4′ 4′	8′ 4′ 8′		• • •				C 1177
DensDeck® Prime Roof Board – Premium, non-structural roof board engineered with a proprietary, non asphaltic coating to enhance bonding in commercial roofing systems. Fiberglass mat facings with water-resistant, treated core.	1/4″ 1/4″ 1/2″ 1/2″	4′ 4′ 4′ 4′	4′ 8′ 4′ 8′		• • • •				C 1177
DensDeck® DuraGuard Roof Board – An enhanced roof board incorporating a low perm, integrated coating for self-adhesive and built up roofing systems with all the features of DensDeck roof board.	1/4″ 1/4″ 1/2″ 1/2″	4′ 4′ 4′ 4′	4′ 8′ 4′ 8′		• • • •				C 1177

Note: Some products are not available at all plants or locations. Call sales office listed on back cover for specific product availability.
***As described and tested in accordance with ASTM E 136.**

Dens Brand Fiberglass Mat Gypsum Boards
continued next page

4.6.9 Gypsum Board—Georgia-Pacific Specifications (Continued)

Product Selection Guide



Dens™ Brand Fiberglass Mat Gypsum Panels continued from previous page

Product	Dimensions			Edge					Standard
	TH	W	L	TE	S	RE	B	DB	ASTM
DensDeck®, DensDeck® Prime and DensDeck® DuraGuard Fireguard® Type X Roof Board – Use as described above. Can replace 5/8" Type X gypsum board under prefix "P" in UL Fire Resistance Directory. Qualifies for numerous 1- and 2-hour fire-rated assemblies.	5/8" 5/8"	4' 4'	4' 8'		• •				C 1177 C 1177
DensGlass™ Exterior Sheathing (formerly DensGlass Gold® Exterior Sheathing) – Fiberglass mat exterior substrate panel for walls, ceilings and soffits. Ideal for EIFS, brick and other exterior cladding applications.	1/2"	4'	8', 9', 10'		•				C 1177
DensGlass™ Fireguard® Type X Exterior Sheathing – Use as described above. Can replace 5/8" Type X sheathing in fire-rated wall assemblies. Qualifies for numerous 1- and 2-hour fire-rated assemblies. UL/ULC Classified.	5/8"	4'	8', 9', 10'		•				C 1177
DensGlass™ Ultra Shaftliner Panels – For use with metal stud shaftwall, stairwell or area separation wall systems. Fiberglass mats increase weather resistance and resist the growth of mold. Patented product with moisture-resistant, treated, Type X core. Beveled edges facilitate fit into metal components. UL/ULC Classified.	1"	23-7/8"	8' to 12'					•	C 1658 Applicable Sections of C 442 and C 1396

Veneer Board

Product	Dimensions			Edge					Standard		
	TH	W	L	TE	S	RE	B	DB	ASTM	FEDERAL	CSA
ToughRock® Veneer Plaster Base (Blue Board) – Gypsum wallboard with high-suction face paper. Use in conjunction with DensArmor Cote™ Interior Veneer Plaster and PearlCote™ Interior Veneer Plaster.	1/2"	4'	8' to 16'	•					C 588 C 1396	SS-L-30d Type VI Grade R	A82.27
ToughRock® Fireguard® Type X Veneer Plaster Base – Use as described above. Increases fire rating to same level as ToughRock Fireguard Type X gypsum board. UL/ULC Classified.	5/8"	4'	8' to 16'	•					C 588 C 1396 Type X	SS-L-30d Type VI Grade X	A82.27 M
ToughRock® Fireguard® Type C Veneer Plaster Base – Use as described above. Noncombustible Fireguard Type C core. Increases fire rating to same level as ToughRock Fireguard Type C gypsum wallboard. UL and ULC Classified.	1/2"	4'	8' to 12'	•					C 588 C 1396 Type X	SL-L-30d Type III Grade R	A82 27n

Textures and Plaster

Product	Package Size	Coverage	Standards
			ASTM
PearlCote™ Interior Veneer Plaster – A one-coat plaster application designed for commercial or residential use on walls or ceilings to resist abrasion or damage while maintaining moisture and mold resistance (when tested, as manufactured, per ASTM D 3273).	50-lb. bags	150 sq. ft. per bag	C 587
ToughRock™ Regency Ceiling Textures/Polystyrene – For spray application only. A high-quality aggregate finish with superior ceiling coverage. For use with gypsum board or concrete ceilings. Not recommended for high-moisture areas such as bathrooms.	35-lb. bags 40-lb. bags 50-lb. bags	250 sq. ft. per bag 285 sq. ft. per bag 350 sq. ft. per bag	
ToughRock™ Wall and Ceiling Texture – A decorative spray application for both walls and ceilings. Commonly used for splatter application, knock-down and orange peel type textures.	50-lb. bags	Up to 2,000 sq. ft. per bag depending on finish	

Note: Some products are not available at all plants or locations. Call sales office listed on back cover for specific product availability.
***When tested, as manufactured, per ASTM D 3273.**

By permission, Georgia-Pacific LLC, Atlanta, Georgia.

4.6.9 Gypsum Board—Georgia-Pacific Specifications (Continued)

Product Selection Guide



ToughRock® Gypsum Board

Product	Dimensions			Edge					Standard		
	TH	W	L	TE	S	RE	B	DB	ASTM	FEDERAL	CSA
ToughRock® Gypsum Board – For interior walls and ceilings. Accommodates wide range of decorative treatments.	1/4″ 3/8″ 1/2″	4′ 4′ 4′	8′ to 12′ 8′ to 12′ 8′ to 12′	• • •	• •	 •			C 36 C 1396	SS-L-30d Type III Grade R	A82.27 M
ToughRock® Fireguard® Type X Gypsum Board – Noncombustible* gypsum core. Interior wall, floor and ceiling applications. Can be used in fire-rated assemblies. Meets basic Type X requirements.	5/8″	4′	8′ to 16′	•	•	•	•		C 36 Type X C 1396	SS-L-30d Type III Grade X	A82.27 M
ToughRock® Fireguard® Type C Gypsum Board – Use as described above. Appropriate for commercial applications requiring extended fire resistance ratings.	1/2″ 5/8″	4′ 4′	8′ to 16′ 8′ to 16′	• •	•	• •	• •		C 36 Type X Premium C 1396	SS-L-30d Type III Grade R	A82.27 M
ToughRock® Moisture-Guard® (Greenboard) – Water-resistant gypsum core and paper surfacing.	1/2″	4′	8′, 10′, 12′	•					C 630 C 1396	SS-L-30d Type VII Grade W	A82.27 M
ToughRock® Fireguard® Type X Moisture-Guard® – Use as described above. Available in 1/2″ and 5/8″ with fire-resistant Type X core.	1/2″ 5/8″	4′ 4′	8′ to 12′ 8′ to 12′	• •					C 630 Type X C 1396	SS-L-30d Type VII Grade W, X	A82.27 M

ToughRock® Specialty Products

Product	Dimensions			Edge					Standard		
	TH	W	L	TE	S	RE	B	DB	ASTM	FEDERAL	CSA
ToughRock® 54″ Wide Gypsum Board – For interior walls and ceilings. Accommodates wide range of decorative treatments. Eliminates filler strip.	1/2″ 5/8″	54″ 54″	8′ to 12′ 8′ to 12′	• •					C 36 C 1396	SS-L-30d Type III Grade R	A82.27 M
ToughRock® CD® Ceiling Board – Specially formulated core and paper ceiling board designed for water-based, textured ceiling applications. Sag resistant.	1/2″	4′	12′	•					C 1395 C 1396	SS-L-30d Type III Grade R	
ToughRock® Fireguard® Type X Soffit Board – Soffit board with treated paper face bonded to specially formulated core designed to resist sag and moisture. For exterior use such as outdoor building soffits, carports and outdoor applications where there is no direct exposure to weather.	1/2″ 5/8″	4′ 4′	8′, 9′, 10′ 8′, 9′, 10′	• •					C 931 C 1396		A82.27 M
ToughRock® Sound Deadening Board – Use with 1/2″ ToughRock Fireguard Type C or 5/8″ ToughRock Fireguard Type X to meet requirements for sound and fire resistance. Manufactured in Edmonton, AB only.	1/4″	4′	8′	•					C 442 C 1396	SS-L-30d Type IV Grade R	A82.27 M
ToughRock® FlexRoc® Gypsum Board – High flex gypsum board designed for inside and outside radius curve installations including archways, columns, curved columns, curved partition walls and curved stairways.	1/4″	4′	8′	•					C 36 C 1396	SS-L-30d Type III Grade R	A82.27 M
ToughRock® Fireguard® Type X Abuse Guard® Gypsum Board –Abuse-resistant gypsum board for high traffic areas where surface durability and surface indentation are important. Specifically formulated to offer greater abrasion, rubbing, scraping and gouging resistance than regular paper-faced drywall.	5/8″	4′	12′	•					C 36 C 1396	SS-L-30d Type III Grade X	A82 M

***As described and tested in accordance with ASTM E 136.**
Note: Some products are not available at all plants or locations. Call sales office listed on back cover for specific product availability.

4.7.0 Joint Treatment Systems



Product Selection Guide

Joint Treatment Systems

Product	Package Size	Coverage	Standards
		ASTM	
DensCote™ Joint Compound – All purpose ready-mix formula–use for bedding tape, finishing joints, filling corner bead, spotting, skim coating and texturing.	61.7-lb. pails 48-lb. box	61.7 lbs. per 500 sq. ft.	C 475
ToughRock® All-Purpose Dry Compound – Use for bedding tape, finishing joints, filling corner bead, spotting, skim coating and texturing.	25-lb. bags	25-lbs. per 400 sq. ft. for joints; 15-50 lbs. per 1,000 sq. ft. for texturing	C 475
ToughRock® Setting Compounds – Allows complete taping and finishing in one day. Recommended for cold weather and slow drying conditions. Hardens by setting, not drying. Available 45- and 90-minute. Ideal products for patch and repair jobs.	33-lb. bags 15-kg. bags	1,800 sq. ft. per 33-lb. bag	C 475
ToughRock® Sandable Setting Compounds – Same use as ToughRock Setting Compounds. Applies and sands easier than ToughRock Setting Compounds. Available in 20-, 45- and 90-minute.	18-lb. bags 24-lb. bags 11-kg. bags	1,000 sq. ft. per 18-lb. bag 1,300 sq. ft. per 24-lb. bag	C 475
ToughRock® Ready-Mix All-Purpose Joint Compound – Pre-mixed, ready to use for bedding tape, finishing joints, skim coating and texturing.	12-lb. pails 61.7-lb. pails 48-lb. ctn. 20-kg. pails 28-kg. pails 27-kg. ctn.	61.7 lbs. per 500 sq. ft.	C 475
ToughRock® Lightweight Joint Compound – Pre-mixed, ready to use for finishing joints and cornerbead. Shrinks less and is easier to sand than All Purpose.	4.5-gallon cartons & pails 1-gallon pail 17-liter cartons	4.5 gallons per 500 sq. ft.	C 475
ToughRock® Semi-Light Joint Compound – Pre-mixed, ready to use for bedding tape, finishing joints, cornerbead and skim coating.	3.5 and 4.5-gallon cartons & pails 23-kg. cartons	4.5 gallons per 500 sq. ft.	C 475
ToughRock® Ready-Mix Topping Compound – Pre-mixed and ready to use. Finish applications only. Very white in color, easy to sand.	61.7-lb. pails 48-lb. cartons	40 lbs. per 500 sq. ft.	C 475
ToughRock® Fire-Halt® Sealant – A noncombustible fast-setting compound for use as a firestop sealant for penetrations such as pipes, conduit and telephone cables in fire-resistive assemblies; and as filler for the flutes in steel decks. Listed with Warnock Hersey International/Intertek Testing Services.	15-lb. pails 33-lb. bags	1 lb. powder mixed will fill 30 cubic inches	C 475
ToughRock™ Tape – Special 2-1/16" wide paper tape. Reinforces gypsum joints. Pre-creased for ease of application.	75-ft. rolls 250-ft. rolls 500-ft. rolls	400' per 1,000 sq. ft. of gypsum board	C 475

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4.8.0 Engineered Wood Products

4.8.1 Plywood Grades per APA—Engineered Wood Association

Sanded Plywood Grade AA—Both faces A-grade, D-grade inner plies. Used for cabinets, built-ins, furniture, and other interior applications where a smooth surface is required.

Sanded Plywood Grade A-A Exterior—Grade A both faces and C-grade inner plies bonded with exterior glue. Finds application in fences, built-ins, tote boxes, boats, commercial refrigerators.

Sanded Plywood Grade A-B—Grade A face and grade B back with grade D inner plies. Used as a substitute for grade A-A where appearance on only one side is important.

Sanded Plywood Grade A-B Exterior—Grade A face and grade B back with C-grade inner plies bonded with exterior glue. Used as a substitute for A-A Exterior where the appearance of only one face is important in an exterior application.

Sanded Plywood A-C Exterior—Grade A face and grade C back with grade C inner plies bonded with exterior glue. Used in soffits, fences, truck linings, and farm buildings where high-moisture applications are required and only one face is required for appearance.

Sanded Plywood A-D—Grade A face and grade D back with grade D inner plies bonded with either interior or exterior glue. Used for paneling, shelving, partitions where smooth appearance is required on only one face.

4.8.1.2 Plywood Veneer Grades

A—Smooth, paintable; wood or synthetic repairs permitted. Some minor splits permitted.

B—Solid surface, light knots to 1 in. across grain permitted. Wood or synthetic repairs permitted.

C—Plugged. Splits limited to 1/8-in. width and knotholes or other defects limited to ¼ in. × ½ in. Wood or synthetic repairs permitted.

C—Tight knots to 1½ in. Knot holes to 1 in. across grain and some to 1½ in. if total width of knots and knotholes is within specified limits.

D—Knots and knotholes to 2½-in. width across grain and ½ in. larger with specified limits. Stitching permitted.

4.8.2 Composite Panels—OSB, Waferboard, Particleboard, MDF

Oriented Strand Board (OSB)—Cross-oriented layers of thin, rectangular wood strips approximately 1 in. × 6 in. (2.5 × 15 cm) bonded together with resin adhesives. The external layers of wood strips or strands are oriented, or aligned along the panel's strength axis, and the inner layers are cross-oriented. Composite panels are widely used for subflooring, roof decking, and exterior sheathing.

Waferboard—Similar in construction to OSB, using rectangular wood flakes but the layers are not oriented as they are in the OSB.

Particleboard—Also called *chipboard*, this composite panel is manufactured from wood particles, wood chips, and sawmill shavings bonded together with a synthetic resin. This board is the lightest and weakest type of fiberboard and is prone to expansion and discoloration when exposed to moisture.

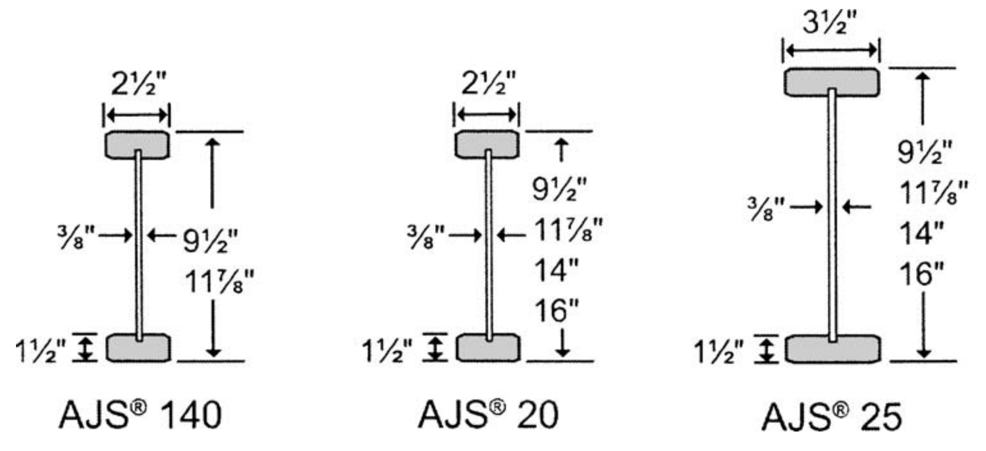
Medium-Density Fiberboard (MDF)—Composed of cellulosic fibers combined with a synthetic bonding process, MDF is flat, smooth, uniform, and dense. This product can be machined to create intricate patterns with precise tolerances. MDF finds application in doors, jambs, millwork, laminate flooring, and paneling.

Hardboard (HB)—This composite panel is manufactured with interfelted lingo-cellulosic fibers consolidated under pressure. Hardboard is very dense and resists scuffing or abrasion. It can be glued or fastened together with screws and can have faces of decorative paper or plastic laminate applied. HB finds application in prefinished panels, siding, exterior trim, door skins, and perforated board.

4.8.3 Wood Joists and Glulams

Framing systems utilizing engineered wood products include wood joists combining solid flanges and composite webs and laminated structural and decorative framing members referred to as *glulams*. These structural members resist warping and twisting and avoid waste due to cutoffs and rejected natural wood framing members.

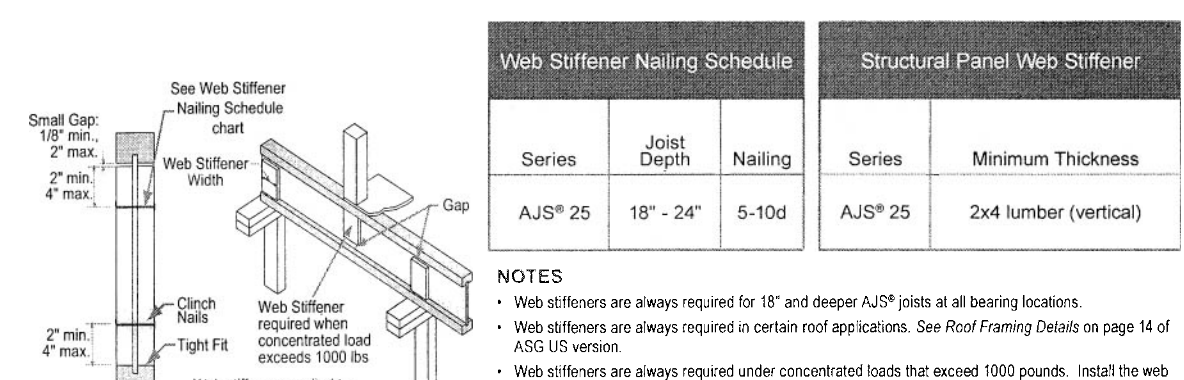
4.8.3.1 Typical Wood Joist Profiles—Depths from 9½ to 16 in.



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4.8.3.2 Wood Joists 18 to 24 in. Require Web Stiffeners

Stiffeners are required at all bearing locations and for certain roof applications.



Web Stiffener Nailing Schedule		
Series	Joist Depth	Nailing
AJS® 25	18" - 24"	5-10d

Structural Panel Web Stiffener	
Series	Minimum Thickness
AJS® 25	2x4 lumber (vertical)

NOTES

- Web stiffeners are always required for 18" and deeper AJS® joists at all bearing locations.
- Web stiffeners are always required in certain roof applications. *See Roof Framing Details* on page 14 of ASG US version.
- Web stiffeners are always required under concentrated loads that exceed 1000 pounds. Install the web stiffeners snug to the top flange in this situation. Follow the nailing schedule for intermediate bearings.

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4.8.3.3 Engineered Wood Studs Constructed of Laminated Veneer Lumber

These studs reduce waste and provide superior strength and straight walls.

1 1/2" VERSA-STUD 1.7 2650 Allowable Design Values

Product	Bending F_b [psi] (1) (2)	Compression Parallel to Grain F_c [psi] (1)	Horizontal Shear F_v [psi] (1)	Modulus of Elasticity E [psi]
VERSA-STUD® 1.7 2650 1 1/2"x5 1/2"	**3005**	**3000**	**285**	**1,700,000**
Spruce Pine Fir (North) #1 / #2 Grade 2x6	1310	1150	135	1,400,000
Hem-Fir #2 Grade 2x6	1270	1300	150	1,300,000
Western Woods #2 Grade 2x6	1010	900	135	1,000,000

(1) Load duration factor may be applied to design stresses.
(2) Repetitive member and size factors have been applied to bending stresses.

— Design values are for loads applied to the narrow face of the studs.
— Dimension lumber values taken from 2001 Edition, *NDS Design Values for Wood Construction* (per 2003 IBC/IRC).

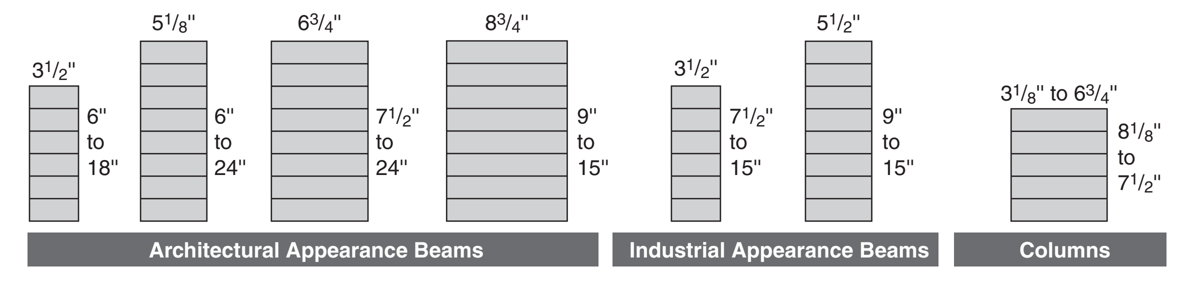
1 1/2" VERSA-STUD 1.7 2650 Design Properties

Width [in]	Depth [in]	Weight [lb/ft]	Allowable Shear [lb]	Allowable Moment [lb-ft]	Moment of Inertia (I) [in^4]
1 1/2	3 1/2	1.5	998	776	5.4
1 1/2	5 1/2	2.4	1568	1821	20.8
1 1/2	7 1/4	3.2	2066	3069	47.6
1 1/2	9 1/4	4.0	2636	4862	98.9
1 1/2	11 1/4	4.9	3206	7038	178.0

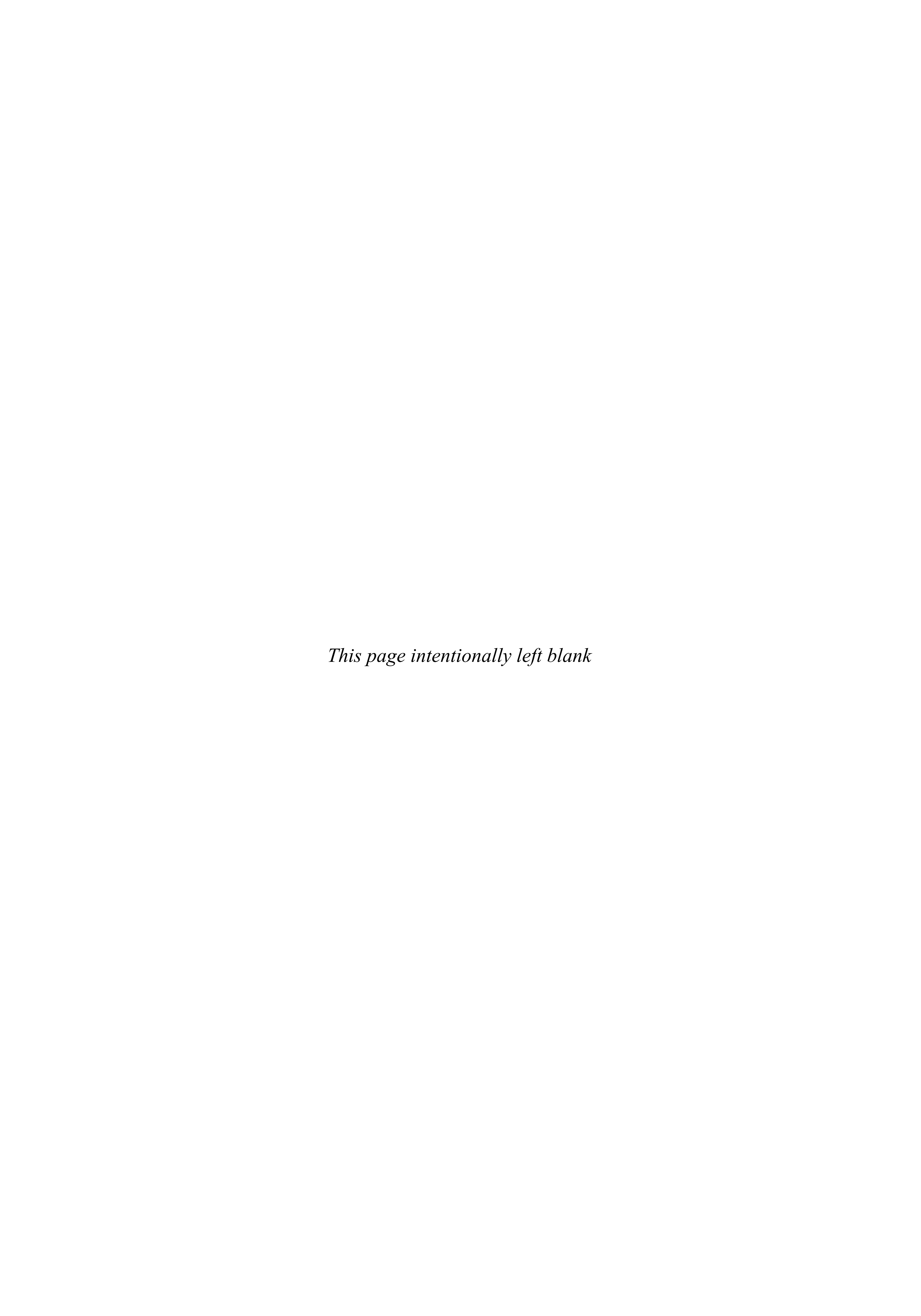
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4.8.3.4 Typical Profiles of Industrial Appearance Glulams

Architectural appearance glulams are available in a wide variety of wood species and finishes.



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Section

5

Fireproofing and Soundproofing

Contents

5.0.0 Fireproofing Is a Misnomer

Because no structure is theoretically *fireproof*; fire *resistance* is a better term. Fire resistance is the duration during which a structure or a structural assembly retains adequate integrity and stability after being subjected to a standard fire test such as the ASTM E 119. Fire ratings are expressed in the number of hours that the assembly or element can withstand fire relative to other assemblies or elements.

5.0.1 Active Fire Protection System Components

- Automatic sprinkler systems
- Smoke and fire detector and alarm systems
- Water supply systems, hose cabinets, fire extinguishers
- Fire department response teams

5.1.0 Five Types of Construction Relating to Fire Ratings

Five basic groups of building construction in the United States are referred to as types I, II, III, IV, and V with type I being the least combustible and type V the most combustible.

- Type I—*Fire-resistive* is the least combustible.
- Type II—*Noncombustible* is the second type of least combustible structure. This building type may have structural steel or a concrete structure but have a combustible roof.
- Type III—Rated as *ordinary*, a building can have brick or masonry bearing walls combined with wood joist and other combustible structural parts. Firefighters often categorize ordinary construction as a “lumberyard enclosed by four brick walls.”
- Type IV—This category is known as *heavy timber* or *mill-type* construction. To qualify for this type of structure, the building’s columns must be wood beams 8 in. or thicker in any direction, and wood girders more than 6 in. thick.
- Type V—This type of structure has both interior and exterior wood framing and structural members with dimensions less than those in type IV.

5.1.1 Type of Fire-Resistive Requirements per 1999 National Building Code

TYPICAL FIRE-RESISTIVE REQUIREMENTS FOR STRUCTURAL COMPONENTS (IN HOURS, BASED ON 1999 NATIONAL BUILDING CODE)

	TYPE OF CONSTRUCTION									
	Type 1		Type 2			Type 3		Type 4	Type 5	
	Noncombustible		Noncombustible			Ordinary		Heavy Timber	Wood Frame	
	Protected		Protected		Unprotected	Protected	Unprotected		Protected	Unprotected
	1A	1B	2A	2B	2C	3A	3B	4	5A	5B
Exterior Bearing Walls	4	3	2	1	0	2	2	2	1	0
Structural Frame	4	3	2	1	0	1	0	4x6 roof 6x10 floor 6x8 col. (roof) 8x8 col. (floor)	1	0
Interior Bearing Walls	4	3	2	1	0	1	0	1	1	0
Fire Walls	4	3	2	2	2	2	2	2	2	2
Vert. Openings (Shaft Enclosures)	2	2	2	2	2	2	2	2	1	1
Floors	3	2	1-1/2	1	0	1	0	3" or 4" set on edge plus 1" flooring (or 15/32" plywood)	1	0
Roofs (15 ft. or less in height)	2	1-1/2	1	1	0	1	0	2" or 3" set on edge (or 1-1/8" plywood)	1	0

Note: The above table specifies the fire resistance ratings required based on conditions such as maximum heights and areas. Increases and reductions in these ratings for specified design considerations are covered in the code.

5.1.2 Fire Resistance Ratings from the International Building Code (IBC)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Structural frame[a] Including columns, girders, trusses	3[b]	2[b]	1	0	1	0	HT	1	0
Bearing walls Exterior[f] Interior	 3 3[b]	 2 2[b]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior Interior[e]	See Table 602 See Section 602								
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	1½[c]	1[c]	1[c]	0[c]	1[c]	0	HT	1[c]	0

For SI: 1 foot = 304.8 mm.

a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

b. Roof supports: Fire-resistance ratings of the structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

c. 1. Except in Factory-Industrial (F-1), Hazardous (H), Institutional (I), Mercantile (M) and Moderate-Hazard Storage (S-1) occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be used for such unprotected members.
2. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.
3. In Type I and Type II construction, fire-retardant-treated wood shall be allowed in buildings not over two stories including girders and trusses as part of the roof construction.

d. An approved automatic sprinkler system is accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

e. For interior nonbearing partitions in Type IV construction also see Section 602.4.6.

f. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

Source: American Institute of Steel Construction, Chicago, Ill.

5.1.3 Fire Ratings—NFPA 5000

	Type I		Type II			Type III		Type IV	Type V	
	442	332	222	111	000	211	200	2HH	111	000
Exterior Bearing Walls[a]										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0[b]	2	2	2	1	0[b]
Supporting one floor only	4	3	2	1	0[b]	2	2	2	1	0[b]
Supporting a roof only	4	3	1	1	0[b]	2	2	2	1	0[b]
Interior Bearing Walls										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting roofs only	3	2	1	1	0	1	0	1	1	0
Columns										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	3	2	2	1	0	1	0	H	1	0
Supporting roofs only	3	2	1	1	0	1	0	H	1	0
Beams, Girders, Trusses, and Arches										
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	2	2	2	1	0	1	0	H	1	0
Supporting roofs only	2	2	1	1	0	1	0	H	1	0
Floor Construction	2	2	2	1	0	1	0	H	1	0
Roof Construction	2	1½	1	1	0	1	0	H	1	0
Interior Nonbearing Walls	0	0	0	0	0	0	0	0	0	0
Exterior Nonbearing Walls[c]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

Note: H = heavy timber members
[a]See 7.3.2.1.
[b]See Section 7.3.
[c]See 7.2.3.2.13, 7.2.4.2.3, and 7.2.5.6.8.

Source: American Institute of Steel Construction, Chicago, Ill.

5.1.4 Fire Load

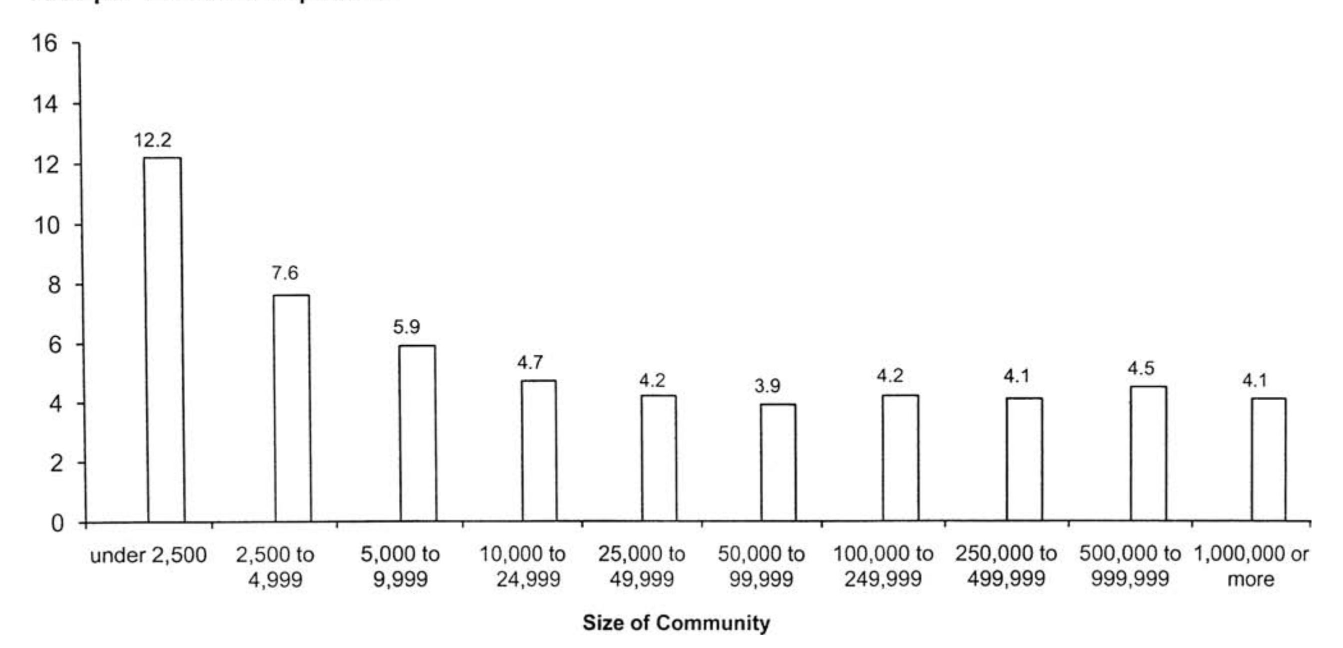
The term *fire load* refers to the amount of combustible material in the building, expressed in terms of wood-equivalent weight of combustible materials in the building per unit building floor area (pounds per square foot).

5.1.4.1 Relationship between Fire Load and Fire Endurance Time

Average Fire Load, psf	Average Fire Load, kg/m^2	Equivalent Fire Endurance (hours)
5	24.4	½
7 ½	36.6	¾
10	48.8	1
15	73.2	1 ½
20	97.6	2
30	146.5	3
40	195.3	4 ½
50	244.1	6
60	292.9	7 ½

Source: American Institute of Steel Construction, Chicago, Ill.

5.2.0 Fires per Thousand Population by Size of Community



Source: NFPA, Quincy, MA.

5.2.1 Fire Loss Rates Nationwide and by Region 2007

Region	Number of Fires per Thousand Population	Civilian Deaths per Million Population	Civilian Injuries per Million Population	Property Loss per Capita
Nationwide	5.2	11.4	58.6	$48.5*
Northeast	5.3	8.2	57.2	32.3
Midwest	5.6	12.5	78.2	50.6
South	5.7	15.9	55.8	39.8
West	3.8	6.7	45.7	73.3*

*Includes the California Fire Storm 2007.

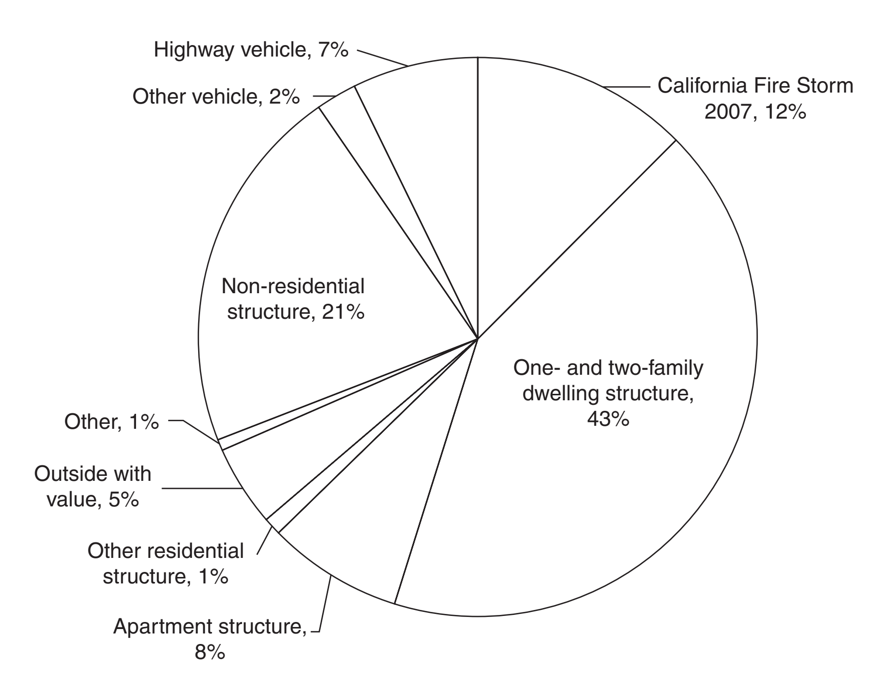
Source: NFPA, Quincy, MA.

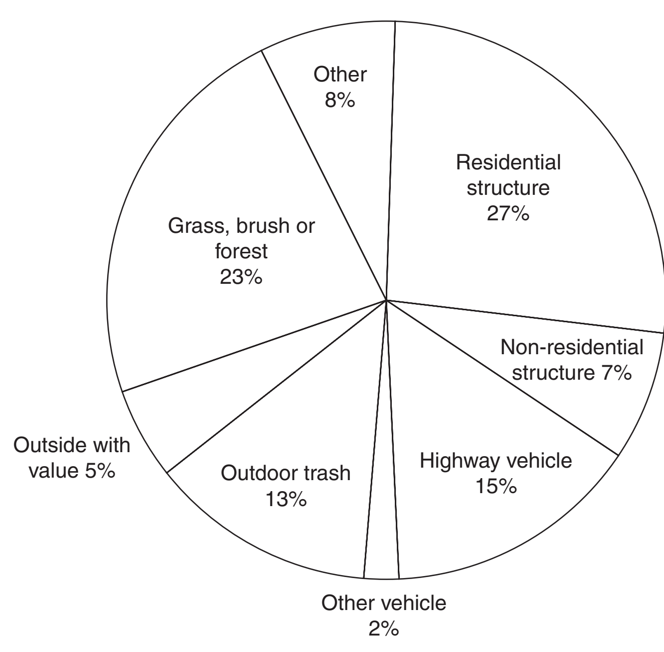
5.2.2 U.S. Fire Loss for Year 2007 Compared with Prior Years

Reported to Fire Departments	2007	COMPARED TO 2006	1997	1987	1977
Civilian Deaths	3,430	Up 6%	Down 15%	Down 41%	Down 54%
Firefighter Deaths	102	Up 15%	Up 3%	Down 23%	Down 35%
Civilian Injuries	16,400	Up 7%	Unchanged	Down 31%	Down 42%
Direct Property Damage	$14,639,000,000	Up 29%	Up 72%	Up 104%	Up 211%
Adjusted for Inflation		Up 26%	Up 33%	Up 12%	Down 9%
Civilian Deaths per Thousand Fires	2.2	Down 11%	Down 2%	Down 12%	Down 3%
Civilian Deaths per Million Population	11.4	Up 4%	Down 25%	Down 52%	Down 67%
Property Damage per Structure Fire	$20,053	Up 9%	Up 56%	Up 144%	Up 434%
Adjusted for Inflation		Up 6%	Up 21%	Up 34%	Up 56%

Source: NFPA, Quincy, MA.

5.2.3 Report of Fire Incidents by Major Property Class





Source: NFPA, Quincy, MA.

5.3.0 Steel Structures and Fire Degradation

At high temperatures steel begins to degrade with respect to yield strength and tensile strength. Yield strength begins to degrade at about 790°F (400°C) according to the American Institute of Steel Construction.

5.3.1 ASTM E119 Temperature Endpoint Criteria

Structural Assembly or Member	Temperature Location	Maximum Temperature °F (°C)
Walls and partitions, loaded or not loaded	Average*	250 (139)
	Single point*	325 (181)
Steel columns or beams, not loaded	Steel section average	1,000 (538)
	Steel single point	1,200 (649)
Loaded floor/roof assemblies, the last four criteria also apply in tests on loaded beams	Average*	250 (139)
	Single point*	325 (181)
	Average of steel beams or joints, if spaced at 4 ft or less	1,100 (593)
	Steel deck average	1,100 (593)
	Steel beam section average	1,100 (593)
	Steel beam single point	1,300 (704)
	Tensile pre-stressing steel	800 (427)
	Tensile reinforcing steel.	1,100 (593)

* Maximum temperature increase on the unexposed surface of the assembly.

Source: American Institute of Steel Construction.

5.3.2 Steel Fire Protection Materials

Steel fire protection materials include spray-on cementitious materials or mineral fiber expanded aggregate coating spray-on fire-resistant materials (SFRMs) such as perlite and vermiculite. Energy-absorbing materials such as concrete and gypsum board also create fire resistance, and intumescent materials, applied as paint or caulk, expand upon exposure to high temperatures, forming an insulating layer that can also provide fire protection.

5.4.0 Spray-Applied Fire Resistive Material (SFRM)

Low-density inorganic products such as mineral fiber Blaze-Shield comprised of cementitious-based Monokote have densities of about 15 lb/ft^3 (240 kg/m^3). Although highly efficient, these types of fire protection materials can be easily damaged and removed from structural steel, ductwork, steel electrical conduits and boxes as workers move materials in the building and when subcontractors install other work on or near the protected steel.

Medium-density products such as Duraspray and Pyrocrete have densities in the range of 100 lb/ft^3 (1600 kg/m^3) to 150 lb/ft^3 (2400 kg/m^3) and have highly efficient fire resistivity. These products add weight to the surface to which it is applied and need to be considered in that respect.

High-density products include concrete, either lightweight or regular weight. This material is extremely durable and more expensive to apply, and it adds considerable weight to the surface to which it is applied. Carboline, Fendolite, Albi-crete, Pyrocrete, and Mandoseal are all excellent high-density inorganic systems.

5.4.1 Application of SFRM on Steel

SFRM can be applied to bare, galvanized, or painted steel. Any primers or paints must have been tested per ASTM E 736 to be deemed acceptable for a subsequent application of SFRM, according to the American Institute of Steel Construction (AISC). The AISC recommends eliminating the shop coat of paint and any prime coat when steel is to be sprayed with a fire-resistant coating. When left unpainted, the steel must be clean and free of oil, dirt, and loose mill scale for optimum adhesion. Typically a minimum average bond strength of 80 percent is deemed acceptable for SFRM.

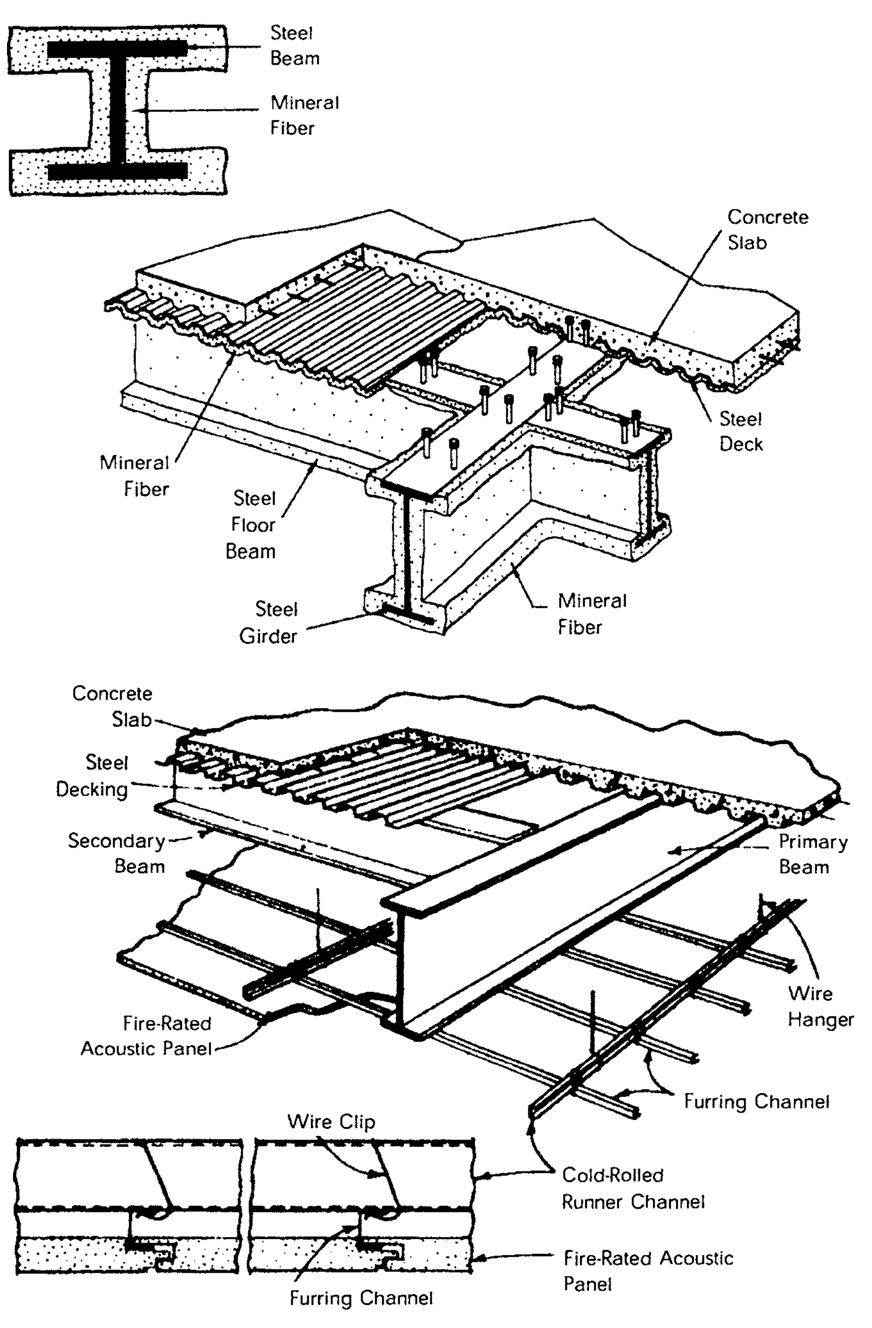
5.4.2 Alternates to Spray-On or Intumescent Fire-Resistant Products

- Filling tubular or other hollow steel shaped structural components with cement
- Applying metal lath and plaster
- Installing rated suspended ceilings or rated roof-ceilings
- Enclosing structural members in gypsum board products or mineral board products

5.5.0 Intumescent Materials

Intumescent material creates a thermal barrier on the surface to which it is applied. In the case of structural steel, intumescent coatings delay the time it takes to heat the steel to the point where it loses structural integrity. When this material is applied to walls or other interior surfaces at about a 6-mil thickness, when temperatures reach about 300°F, the “paint” will swell to a black foam about 1 in. thick containing millions of tiny closed, fire-resistant cells forming a barrier to retard rapid heating of the material’s surface.

5.6.0 Typical Steel Fire Protection Details



Source: American Iron and Steel Institute.

5.6.1 Gypsum Product Fire Protection

- *1-h ceiling*—Two layers of 5/8-in. type X drywall directly applied to framing. The second layer applied at right angles to the base layer.
- *2-h ceiling*—Four layers of 5/8-in. type X drywall.
- *1-h membrane*—Two layers of 5/8-in. type X drywall applied directly to the wall framing or furring. Joints of second layer are offset from joints of base layer.

5.6.2 Roof and Ceiling Assemblies with Membrane Protection—Built-Up Roof

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Built Up Roof		Maximum Joist Spacing (in.)	Minimum Primary Support Member	UL Design Number
			Deck Material Description	Insulation			
1 Hr.	Exposed Grid	12K1	22 MSG Min.	Fiber Board	84	W8 x 17	P201
		10K1	26 MSG Min.		48	W6 x 12	P202
		10K1	26 MSG Min.		48	20G@13plf	P211
		12K3	28 MSG Min.		72	20G@13plf W8 x 17	P214
		12K1	26 MSG Min.		72	20G@13plf W6 x 12	P225
		12K3	24 MSG Min.	Building Units	48	NS	P227
		12K3	26 MSG Min.	Fiber Board	72	20G@13plf W6 x 12	P230
		12K1	26 MSG Min.	Insulating Concrete	48	20G@14plf* W8 x 15	P231
		12K3	24 MSG Min.	Foamed Plastic	72	W8 x 15	P235
		10K1	28 MSG Min.	Insulating Concrete	72	20G@13plf W8 x 15	P246
		12K5	26 MSG Min.	Fiber Board	48	W6 x 12	P250
		12K1	28 MSG Min.	Insulating Concrete	72	20G@13plf W6 x 12	P251
		10K1	22 MSG Min.	Fiber Board	72	W6 x 12	P254
		10K1	28 MSG Min.	Insulating Concrete	72	W8 x 15	P255
		10K1	24 MSG Min.	Fiber Board	72	NS	P259
		12K1	28 MSG Min.	Insulating Concrete	72	20G@13plf W6 x 12	P261
		12K1	26 MSG Min.	Insulating Concrete	72	20G@14plf* W8 x 15	P264
		10K1	Metal Roof Deck Panels	Batts and Blankets	60	NS	P265
		10K1	26 MSG Min.	Fiber Board	48	W6 x 16	P267
		10K1	Metal Roof Deck Panels	Batts and Blankets	60	NS	P268
		12K1	26 MSG Min.	Insulating Concrete	72	20G@14plf* W8 x 15	P269
	Fiber Board	10K1	24 MSG Min.	Fiber Board	NS	W6 x 16	P301
		10K1	22 MSG Min.		48	NS	P302
		10K1	22 MSG Min.		NS	W6 x 16	P303
	Gypsum Board	12K3	26 MSG Min.	Insulating Concrete	60	W8 x 24	P509
		12K3	24 MSG Min.	Fiber Board	72	20G@13plf W8 x 13	P510
		10K1	20 MSG Min.	Fiber Board	48	NS	P519

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5.6.2 Roof and Ceiling Assemblies with Membrane Protection—Built-Up Roof (Continued)

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Built Up Roof		Maximum Joist Spacing (in.)	Minimum Primary Support Member	UL Design Number
			Deck Material Description	Insulation			
1 1/2 Hr.	Exposed Grid	12K1	26 MSG Min.	Fiber Board	72	20G@13plf W6 x 12	P225
		12K3	24 MSG Min.	Building Units	48	NS	P227
		12K3	26 MSG Min.	Fiber Board	48	20G@13plf W6 x 12	P230
		12K1	26 MSG Min.	Insulating Concrete	48	20G@14plf* W8 x 24	P231
		12K5	26 MSG Min.	Fiber Board	48	W6 x 12	P250
		12K1	28 MSG Min.	Insulating Concrete	72	20G@13plf W6 x 12	P251
		10K1	24 MSG Min.	Fiber Board	72	NS	P259
		10K1	Metal Roof Deck Panels	Batts and Blankets	60	NS	P265
		10K1	20 MSG Min.	Fiber Board	48	NS	P266
		10K1	Metal Roof Deck Panels	Batts and Blankets	60	NS	P268
		12K1	26 MSG Min.	Insulating Concrete	72	20G@14plf* W8 x 24	P269
	Fiber Board	10K1	24 MSG Min.	Fiber Board	NS	W6 x 16	P301
	Metal Lath	12K5	22 MSG Min.	Fiber Board	72	NS	P404
	Gypsum Board	12K3	24 MSG Min.	Fiber Board	72	20G@13plf W8 x 13	P510
2 Hr.	Exposed Grid	10K1	24 MSG Min.	Fiber Board	72	W6 x 12	P237
		12K1	28 MSG Min.	Insulating Concrete	72	20G@13plf W6 x 12	P251
		10K1	20 MSG Min.	Fiber Board	48	NS	P266
	Fiber Board	10K1	24 MSG Min.	Fiber Board	NS	W6 x 16	P301
	Metal Lath	12K5	22 MSG Min.	Fiber Board	72	NS	P404
	Gypsum Board	10K1	22 MSG Min.	Fiber Board	72	20G@13plf	P514
			20 MSG Min.		48	NS	P519
		14K1	26 MSG Min.	Insulating Concrete	66	NS	P520
3 Hr.	Metal Lath	10K1	28 MSG Min.	Insulating Concrete	48	NS	P405

* Special Area Requirements
NL = Not Listed
NS = Not Specified

Source: American Iron and Steel Institute.

5.6.3 Floor and Ceiling Assemblies with Membrane Protection—Concrete Deck

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Concrete		Maximum Joist Spacing (in.)	Minimum Primary Support Member	UL Design Number
			Minimum Thickness (in.)	Type			
2 Hr.	Exposed Grid	10K1	2.5	NW	24 (48)	20G@13plf W8 x 24	G229
		10K1	2.5		24 (48)	20G@13plf W6 x 12	G243
		10K1	2.5		72	20G@14plf* W6 x 12	G256
		10K1	2.5		24 (48)	20G@13plf W8 x 31	G268
	Gypsum Board	10K1	2	NW	24 (48)	NS	G505
		10K1	2.5		24 (48)	20G@14plf* W8 x 31	G514
		10K1	2.5		24 (48)	20G@13plf W10 x 21	G523
		10K1	2.5		24 (48)	20G@13plf W8 x 24	G529
		10K1	2.5		24 (48)	20G@13plf W10 x 21	G547
3 Hr.	Acoustical	12K1, 18LH02	3.25	LW, NW	NL	20G@13plf W8 x 15	D216 D219
	Concealed Grid	10K1	3.5	NW	24 (48)	20G@13plf W8 x 20	G033
		10K1	3.25		30 (48)	20G@13plf W10 x 21	G036
	Exposed Grid	10K1	3.5	NW	48	20G@14plf* W6 x 12	G205
		10K1	3.5		24 (48)	W6 x 12	G213
		10K1	3.25		24 (48)	20G@13plf W8 x 24	G229
		10K1	3.5		48	20G@14plf* W6 x 12	G256
		10K1 (22 ksi max.)	2.63		24 (48)	20G@13plf W8 x 31	G268
	Gypsum Board	10K1	3	NW	24 (48)	20G@13plf W10 x 21	G523
		10K1	2.75		24 (48)	20G@13plf W8 x 24	G529
		10K1	3		24 (48)	20G@13plf W10 x 21	G547

* Special Area Requirements
NL = Not Listed
NS = Not Specified

5.6.3 Floor and Ceiling Assemblies with Membrane Protection—Concrete Deck (Continued)

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Concrete		Maximum Joist Spacing	Minimum Primary Support Member	UL Design Number
			Minimum Thickness (in.)	Type			
1 Hr.	SAFRM	NS	2.5	LW, NW	NL	W8 x 28	D759
		10K1	2.5				D779
		10K1	2.5				D780
		NS	3.25	LW			D782
		10K1*	2.5	LW			D925
			3.5	NW			
		16K6*	NS	LW, NW	42	20G@20plf W8 x 28	G701
		16K6	3	LW	50.5	NS	G702
			3.75	NW			
		16K6*	2.5	LW, NW	42	NS	G705
		16K6	3	LW	50.5	NS	G706
			3.75	NW			
		16K6*	2.5	LW, NW	42	20G@20plf W8 x 28	G708
		NS	2.5		42	W8 x 28	G709
		16K6*	2.5		42	20g@20plf W8 x 24	G801
		12K1	3	LW	50.5	NS	G802
			3.75	NW			
1 1/2 Hr.	SAFRM	NS	2.5	LW, NW	NL	W8 x 28	D759
		10K1	2.5				D779
		10K1	2.5				D780
		NS	3.25	LW			D782
		10K1*	3	LW			D925
			4	NW			
		16K6*	2.5	LW, NW	42	20G@20plf W8 x 28	G701
		16K6	3.5	LW	50.5	NS	G702
			4.5	NW			
		16K6*	2.5	LW, NW	42	NS	G705
		16K6	3.5	LW	50.5	NS	G706
			4.5	NW			
		16K6*	2.5	LW, NW	42	20G@20plf W8 x 28	G708
		NS	2.5		42	W8 x 28	G709
		16K6*	2.5		42	20G@20plf W8 x 24	G801
		12K5	3.5	LW	50.5	NS	G802
			4.5	NW			

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5.6.4 Floor and Ceiling Assemblies with Spray-Applied Fire-Resistive Materials—Concrete Deck

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Concrete		Maximum Joist Spacing	Minimum Primary Support Member	UL Design Number
			Minimum Thickness (in.)	Type			
2 Hr.	SAFRM	NS	2.5	LW, NW	NL	W8 x 28	D759
		10K1	2.5				D779
		10K1	2.5				D780
		NS	3.25	LW			D782
		10K1*	3.25	LW			D925
			4.5	NW			
		16K6*	2.5	LW, NW	42	20G@20plf W8 x 28	G701
		16K6	4	LW	50.5	NS	G702
			5.25	NW			
		16K6*	2.5	LW,NW	42	NS	G705
		16K6	4	LW	50.5	NS	G706
			5.25	NW			
		16K6*	2.5	LW, NW	42	20G@20plf W8 x 28	G708
		NS	2.5		42	W8 x 28	G709
		16K6*	2.5		42	20G@20plf W8 x 24	G801
		12K5	4	LW	50.5	NS	G802
			5.25	NW			
3 Hr.	SAFRM	NS	2.5	LW, NW	NL	W8 x 28	D759
		10K1	2.5				D779
		10K1	2.5				D780
		NS	3.25	LW			D782
		10K1*	4.19	LW			D925
			5.25	NW			
		16K6*	NS	LW, NW	42	20G@20plf W8 x 28	G701
		16K6*	2.75		42	NS	G705
		16K6*	2.75		42	20G@20plf W8 x 28	G708
		NS	2.75		42	W8 x 28	G709
		16K6*	2.75		42	20G@20plf W8 x 24	G801
4 Hr.	SAFRM	10K1	2.5	LW, NW	NL	W8 x 28	D779
		NS	3.25	LW			D782

* Special Area Requirements
NL = Not Listed
NS = Not Specified

By permission, Nucor, Alpharetta, GA.

5.6.5 Roof and Ceiling Assemblies with Spray-Applied Fire-Resistive Materials—Built-Up Roof

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Built Up Roof		Maximum Joist Spacing (in.)	Minimum Primary Support Member	UL Design Number
			Deck Material Description	Insulation			
1 Hr.	SAFRM	10K1	22 MSG Min.	Building Units	NS	NS	P822
		12K3	22 MSG Min.	Fiber Board	NS	W8 x 20	P824
1 Hr. and 1-1/2 Hr.	SAFRM	12K5	28 MSG Min.	Insulating Concrete	96	W6 x 16	P919
1-1/2 Hr. and 2 Hr.	SAFRM	10K1	22 MSG Min.	Building Units	NS	W6 x 16	P728
1 Hr., 1-1/2 Hr. and 2 Hr.	SAFRM	14K4	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P701
		14K4	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P711
		12K3	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P717
		10K1	22 MSG Min.	Foamed Plastic	NS	20G@13plf W8 x 28	P725
		10K1	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P726
		14K4	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P734
		14K4	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P736
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P739
		10K1	22 MSG Min.	Fiber Board	NS	W6 x 16	P740
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P743
		12K3	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P801
		10K1	22 MSG Min.	Fiber Board	NS	20G@13plf W6 x 16	P815
		10K1	22 MSG Min.	Fiber Board	NS	W6 x 16	P816
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P819
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P825
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P827
		12K1	22 MSG Min.	Fiber Board	NS	20G@13plf W8 x 20	P828
		10K1	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P902
		10K1	28 MSG Min.	Insulating Concrete	NS	W8 x 10	P907
		10K1	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P908

(Continued Next Page)

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5.6.5 Roof and Ceiling Assemblies with Spray-Applied Fire-Resistive Materials—Built-Up Roof (Continued)

Restrained Assembly Rating	Protection Material	Minimum Joist Size	Built Up Roof		Maximum Joist Spacing (in.)	Minimum Primary Support Member	UL Design Number
			Deck Material Description	Insulation			
1 Hr., 1-1/2 Hr. and 2 Hr.	SAFRM	10K1	28 MSG Min.	Insulating Concrete	NS	W8 x 10	P920
		12K5	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P921
		10K1	28 MSG Min.	Insulating Concrete	NS	W6 x 16	P922
		10K1	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P923
		10K1	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P925
		12K5	28 MSG Min.	Insulating Concrete	NS	W8 x 10	P926
		14K4	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P927
		12K5	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P928
		12K3	28 MSG Min.	Insulating Concrete	NS	20G@13plf W8 x 10	P929
		10K1	28 MSG Min.	Insulating Concrete	NS	W6 x 16	P936
2 Hr.	SAFRM	12K3	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P718
		12K3	22 MSG Min.	Foamed Plastic	NS	20G@13plf W6 x 16	P720
		12K3	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P729
1 Hr., 1-1/2 Hr., 2 Hr. and 3 Hr.	SAFRM	10K1	22 MSG Min.	Foamed Plastic	NS	20G@13plf W6 x 16	P719
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P722
		10K1	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P723
		10K1	22 MSG Min.	Foamed Plastic	NS	W8 x 28	P732
		10K1*,16K2	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P733
		10K1*	22 MSG Min.	Foamed Plastic	NS	W6 x 16	P826

* Special Area Requirements
NS = Not Specified

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5.7.0 Flame Spread—A Measure of the Spread of Fire within a Room

Flame spread is primarily used for interior finishes such as paint, wallpaper, and fabrics. The ASTM Test Method E-84 is a tunnel test in which the material to be tested is installed as a ceiling of a test chamber. A specimen 20 in. wide by 25 ft long is exposed to a gas flame at one end. The rate at which the flame spreads across the sample specimen, as compared to a scale of 0 for inorganic reinforced cement board to 100 for red oak, is what determines the flame spread number.

ASTM E-84 also tests the opacity of the smoke generated by burning materials and provides a measurement of the amount of smoke released as the material burns. The scale ranges from 0 for inorganic material such as reinforced cement board to 100 for red oak.

5.7.1 Flame Spread Classifications

TYPICAL FLAME SPREAD CLASSIFICATION REQUIREMENTS FOR INTERIOR FINISH BASED ON THE 1999 NATIONAL BUILDING CODE (TABLE 803.4)

Use groups		Required vertical exits and passageways[c]	Corridors providing exit access[i]	Rooms or enclosed spaces[a]
A-1	Assembly, theatres	I	I[e]	II[b]
A-2	Assembly, nightclubs	I	I[e]	II[b]
A-3	Assembly halls, terminals, restaurants	I	I[e]	II[b]
A-4	Assembly, churches	I	II	III
B	Business	I	II	III
E	Educational	I	II	III
F	Factory and industrial	I	II	III
H	High hazard	I	II	III[f]
I-1	Institutional, residential care	I	II	III
I-2	Institutional, incapacitated	I[h]	I[h]	I[h]
I-3	Institutional, restrained	I	I	III
M	Mercantile, walls ceilings	I I	II II	III II[d]
R-1	Residential, hotels	I	II	III
R-2	Residential, multiple-family dwellings	I	II	III
R-3	Residential, 1- and 2-family and multiple 1-family dwellings	III	III	III
S-1	Storage, moderate hazard	II	II	III
S-2	Storage, low hazard	II	II	III
U	Utility, Miscellaneous	II	II	III

(a) Requirements for rooms or enclosed spaces are based upon spaces enclosed in partitions of the building or structure, and where fire-resistance rating is required for the structural elements, the enclosing partitions shall extend from the floor to the ceiling. Partitions which do not comply with this shall be considered as enclosing spaces and the rooms or spaces on both sides thereof shall be counted as one. In determining the applicable requirements for rooms or enclosed spaces, the specific use or occupancy thereof shall be the governing factor, regardless of the use group classification of the building or structure. Where an automatic sprinkler system is installed (in accordance with code provisions) throughout a building, Class II or III interior finish shall be permitted where Class I or II materials, respectively, are required in the table.

(b) Class III interior finish materials are permitted in places of assembly with a capacity of 300 persons or less.

(c) Class III interior finish materials are permitted for wainscoting or paneling for not more than 1000 square feet of applied surface area in the grade lobby where applied directly to a noncombustible base or over furring strips applied to a noncombustible base and fire-blocked (in accordance with code provisions).

(d) Class III interior finish materials are permitted in mercantile occupancies of 3,000 square feet or less gross area occupied for sales purposes on the street floor only (balcony permitted).

(e) Lobby areas shall be not less than Class II.

(f) Where building height is over two stories, Class II shall be required.

(h) Walls and ceilings shall be a minimum of Class II materials in individual rooms of not more than four persons capacity. Where a building is equipped throughout with an automatic sprinkler system (installed in accordance with code provisions), the minimum requirement for interior finish shall be Class II.

(i) In Use Groups A, I-2 and I-3, Class II interior wall finish material shall be permitted as wainscoting extending not more than 48 inches above the floor in corridors providing exit access.

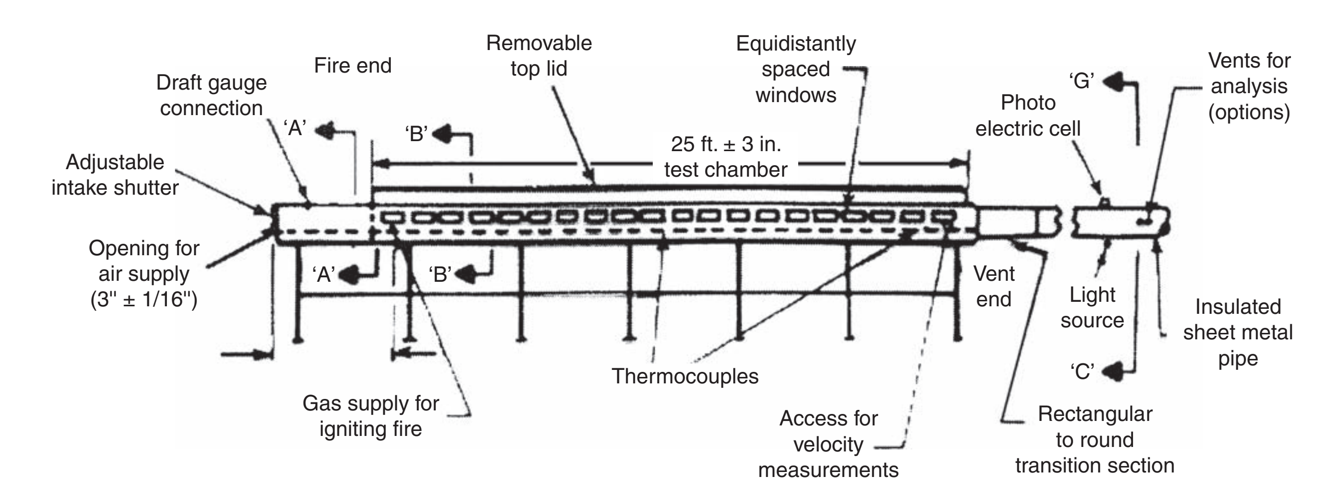
Source: National Building Code.

5.7.2 Interior Finish Requirements and Classifications

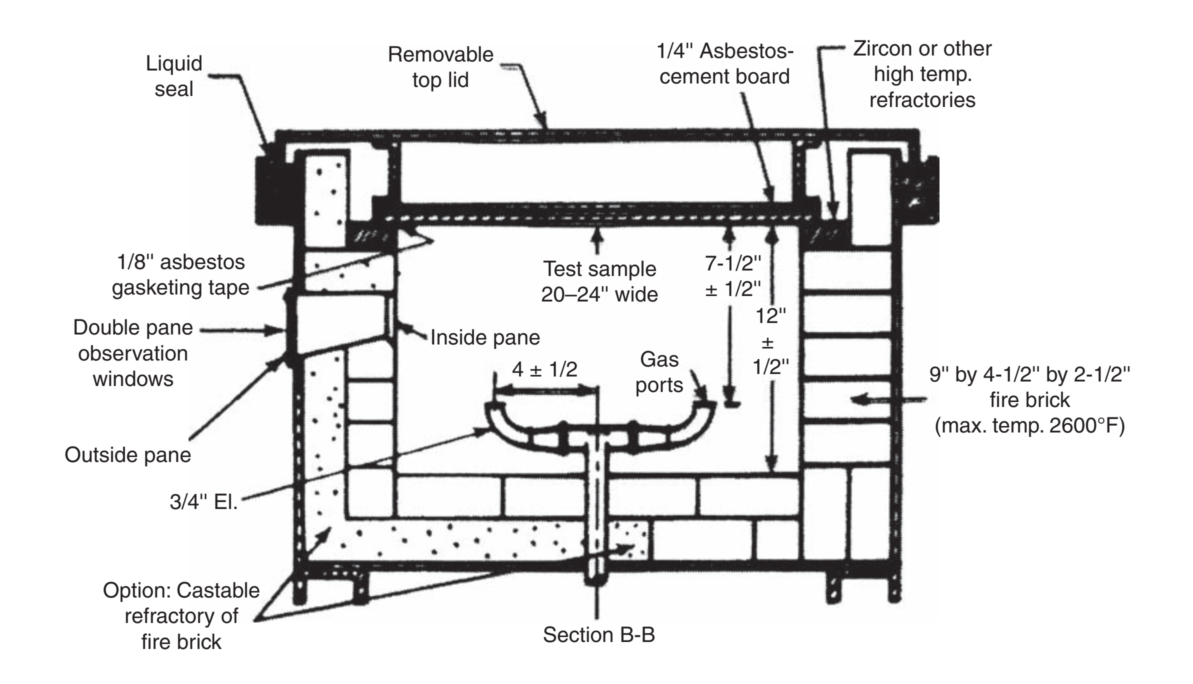
Interior finish requirements relate to "the exposed interior surfaces of buildings including, but not limited to, fixed or movable walls and partitions, columns and ceilings," according to NFPA 101. The principal measurement used for evaluation of interior finishes has been the flame spread of the material as measured by the Steiner tunnel test. This test indicates the relative speed with which a flame will propagate across the surface of the material. A 20-in. (50.8-cm) by 25-ft (7.6-m) specimen is placed on a ledge in the top section of a 25-ft (7.6-m) furnace, face down. A gas burner provides exposure of about 1400°F (778°C) under controlled conditions, and upon completion of the test, the greater the rate of flammability, the higher the rating, which ranges for 0 for asbestos to 100 for red oak flooring.

A diagram of the tunnel test (ASTM E-84) provides the workings of the Steiner test equipment.

Test Furnace for the "Tunnel Test", ASTM E-84



Longitudinal View



5.7.2 Interior Finish Requirements and Classifications (Continued)

INTERIOR FINISH CLASSIFICATIONS

Interior Finish or Flame Spread Classification	Flame Spread Rating or Index	Smoke Developed Rating or Index
Class I (or A)	0 to 25	
Class II (or B)	26 to 75	450 max.
Class III (or C)	76 to 200	

Examples: Material	Flame Spread Rating	Smoke Developed Rating
Inorganic reinforced cement board	0	0
Fire-retardant-treated construction plywood	0 to 25	0 to 80
Fire-retardant-coated construction plywood	0 to 45	0 to 200
Fire-retardant-treated lumber	0 to 25	10 to 360
Red oak lumber	100	100
APA wood structural panels	76 to 200	25 to 270

5.8.0 Fire-Retardant (FR) Paints

FR paints can be used on interior surfaces to reduce flame spread. FR paints are tested using ASTM E-84 protocols to reduce flame spread to 25 or less for class I or class A materials, and from 26 to 75 for class II or class B materials.

5.9.0 Experience with Sprinkler Systems

Sprinklers are effective in reducing fire damage, but these systems must be properly maintained to prove effective and this chart reveals that not all systems operate as they should.

Property Use	Percentage of fires with sprinklers	Percentage of fire where sprinklers operated	Percentage of fires where sprinklers did not operate
Public assembly	23.0	73.9	26.1
Educational	21.6	79.6	20.4
Health care and correctional	2.6	84.6	15.4
All residential	0.7	80.0	20.0
One- and two-family	6.6	82.7	17.3
Apartments	32.8	82.7	17.3
Hotels/motels	52.0	84.9	15.1
Department stores	24.2	80.6	19.4
Offices	12.6	85.9	14.1
Industrial	49.8	91.1	8.9
Manufacturing	3.0	84.0	16.0
Storage	—	82.7	17.3

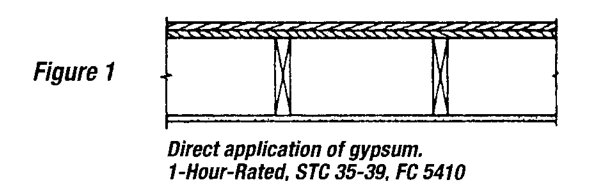
Note: Estimates as percentages of structure fires with sprinkler systems are achieved by dividing the number of structure fires by sprinkler status when known. This excludes fires where sprinklers were present but the fire was too small to test the operational status of the sprinkler.

Source: "U.S. Experience with Sprinklers," NFPA, September 2001.

5.10.0 Fire Endurance and Sound Transmission Qualities of Southern Pine Framed Walls and Floor Systems

FIRE ENDURANCE, SOUND TRANSMISSION

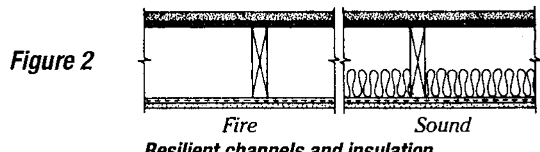
Figure 1



Direct application of gypsum.
1-Hour-Rated, STC 35-39, FC 5410

Wood Joists, Gypsum Wallboard: 1/2" type X gypsum wallboard or veneer base applied at right angles to 2x10 wood joists 16"o.c.

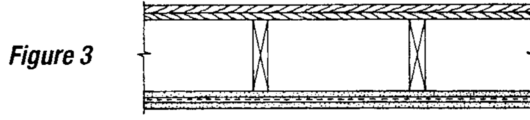
Figure 2



Resilient channels and insulation.
1-Hour-Rated, STC 55-59, FC 5105

Wood Joists, Gypsum Wallboard: 1/2" proprietary type X gypsum wallboard or veneer base applied at right angles to resilient furring channels with 1" Type S drywall screws 12"o.c. Resilient channels applied 24"o.c. at right angles to 2x10 wood joists 16"o.c. with 6d common nail.

Figure 3

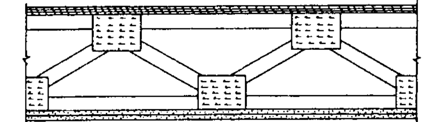


Resilient channels between gypsum layers.
2-Hour-Rated, FC 5724.

Wood Floor, Wood Joists, Gypsum Wallboard: Base layer 5/8" proprietary type X gypsum wallboard or veneer base applied at right angles to 2x10 wood joists 16"o.c. Face layer 5/8" proprietary type X gypsum wallboard or veneer base applied at right angles to resilient furring channels with 1" Type S drywall screws 12"o.c. Resilient furring channel spaced 24"o.c. and nailed at right angles to joists and through base layer.



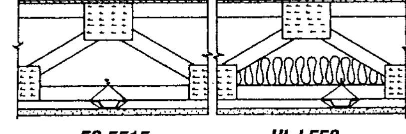
Figure 4



Direct application of two layers of gypsum.
1-Hour-Rated, FC 5512

Gypsum Board, Parallel Chord Wood Trusses: Ceiling — Two layers of 1/2" type X gypsum wallboard or veneer base applied perpendicular to trusses. Base layer end joints staggered 24" and all face layer joints offset 24" from the joints of the base layer. Trusses — chord and web members are fabricated from 2 x 4 lumber with 20 gauge steel connector plates that have a minimum tooth length of 5/16". Trusses are spaced a maximum of 24"o.c. and have a minimum depth of 12".

Figure 5



FC 5515 ***UL L558***
Single gypsum layer on resilient channels.
1-Hour-Rated.

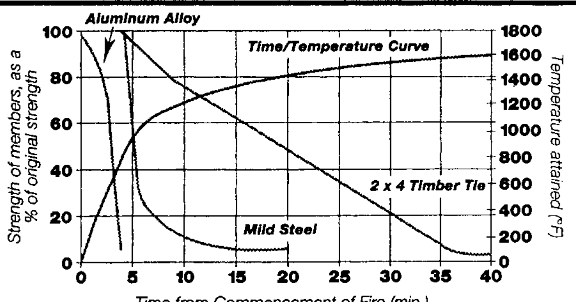
Wood Trusses, Gypsum Wallboard: 5/8" proprietary type X gypsum wallboard or veneer base applied at right angles to steel furring channel with 1" Type S drywall screws 12"o.c. Furring channels 24"o.c. secured with steel wire 48"o.c. perpendicular to parallel chord wood trusses 24"o.c. with a minimum depth of 12".

Dimension lumber joists and rafters have a long history of solid fire endurance performance. The first fire endurance assemblies developed for wood-frame structures were performed using dimension lumber structural members. Further evidence of this exists in the codes where calculating fire endurance assemblies is allowed. Times are assigned for the contribution of wood-frame construction in fire assembly calculation sections (i.e. Section 721.6 and Table 721.6.2(2) of the *2006 International Building Code*). Wood floor and ceiling joists, 16" on center, have a time of 10 minutes assigned to them. For additional information, refer to *Component Additive Method (CAM) for Calculating and Demonstrating Assembly Fire Endurance, Design for Code Acceptance No. 4,* from the American Forest & Paper Association at www.awc.org.

Properly designing a building for fire safety means faithfully executing building code regulations. This means breaking up a building into fire-resistant compartments. With compartments and an efficient protection system in place, fires can be localized and suppressed easily. To prevent fire from spreading from one compartment to the next, the codes require finished assemblies be built to withstand full fire exposure without major damage and, at the same time, act as barriers to heat transfer.

Standard fire tests measure the fire endurance performance of a variety of structural assemblies and boundary conditions that make up compartments. *ASTM Standard E 119* sets forth the conditions of the test and the interpretation of the results. Test results are measured in terms of the assembly's ability to withstand a severe fire for a period of time. Performance times are measured in hours: 1-hour rated; 2-hour rated; etc. The codes reference these hourly requirements for various building construction types and occupancies.

The major sources for dimension lumber fire-endurance assemblies are the *Fire Resistance Design Manual* published by the Gypsum Association, the *Fire Resistance Directory* published by the Underwriters Laboratories, Inc. (UL), and Section 720 and Table 720.1(3) of the *2006 International Building Code.* The major source for metal plate connected truss fire-endurance assemblies is found at www.sbcindustry.com. There are numerous fire-endurance assemblies detailed in these sources. These assemblies include different options, such as the direct application of gypsum, or the use of resilient channels, insulation or suspended ceilings. They range in performance from 45 minutes to 2 hours. The most common dimension lumber and truss fire-endurance assemblies are detailed in Figures 1 – 5 to the left.



Time from Commencement of Fire (min.)
Strength of Steel, Aluminum, and Timber in Relation to Standard Fire Test. AITC Data[1]

(1) Dock & Harbor Authority, London, England, "What About Fire?", American Institute of Timber Construction, 1972, p.3.

Wood has out-performed noncombustible materials in direct comparison fire tests. As illustrated above, a 2x4 timber tie maintained more of its original strength under higher temperatures and for a longer period of time than did aluminum alloy or mild steel.

5.11.0 A Glossary of Firestopping Terms

Ablative: Materials that provide fire resistance by gradually eroding to the flame front at a known or predictable rate.

ABS Pipe: Plastic (Acrylonitrile Butadiene Styrene) pipe used for water distribution, drain, waste, and vent.

Afterglow: Emission of light, usually subsiding, from a material undergoing combustion, but occurring after flaming has ceased.

Annulus (Annular measurement or space): The gap between the penetrating item and the edge of the hole.
In a given penetration, the measurement from the outside diameter (O.D.) of the pipe to the inside diameter (I.D.) of the hole.

Assembly Rating: The rating, in hours, for a wall or floor assembly's ability to prevent the passage of heat or hot gases and to limit a temperature rise to not more than 250°F (120°C) on average or 325°F (160°C) at any one point.

ASTM: American Society for Testing and Materials

ASTM E 119: Tests the performance of walls, columns, floors, and other building components under fire exposure conditions.

ASTM E 814: The method applicable to "through penetration" firestops of various materials and construction. Firestops are tested, and intended for use, in openings in fire-resistive walls and floors.

ASTM E 84: "Standard Method for Surface Burning Characteristics of Building Materials"

AWG: American Wire Gauge

Backer Rod: A combustible polyurethane or polyethylene foam material used to provide support for gunned or troweled sealant within walls or floors.

Backing Material (Foam Backer Rod or Mineral Wool): Combustible or noncombustible material used to provide support for gunned or troweled sealant within walls or floors.

British Thermal Unit (Btu): The heat required to raise the temperature of one pound of water through 1 degree Fahrenheit at atmospheric pressure.

Burn: To undergo combustion.

Burn Patterns: The characteristic configuration of char left by fire. Burn patterns are influenced by wind direction, length of exposure, and type of fuel. They can be used to trace a fire's origin. (Also called fire tracks).

Butt Vertical Joint: The meeting of two vertical veneers whose joint faces are parallel.

Cable Tray: An opened or closed steel ladder or metal tray, which is used to support runs of multiple cables strung throughout buildings.

CAN/ULC-S115: "Standard Method of Fire Tests of Firestop Systems"

Char: A grayish black, crusty material formed by burning organic type sealants.

Closed Piping System: Piping system which is completely enclosed, usually carrying fluids under pressure, such as hot/cold water distribution, sprinkler piping, and chilled water.

CMU: Concrete Masonry Unit. Usually hollow, pre-cast concrete blocks used to construct walls.

5.11.0 A Glossary of Firestopping Terms (Continued)

Combustible Construction: That type of construction that does not meet the requirement for noncombustible construction. Combustible means that a material fails to meet the acceptable criteria of ASTM E 136 (Standard Method of test for Determination of Non-Combustibility in Building Materials).

Combustible Penetrants: Pipes, cables, or other penetrants that may burn or melt out during a fire.

Combustion: A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light, either as a glow or flame.

Concentric: Having a common center like a penetrating item centered in the middle of a through-penetration hole.

CPVC Pipe: High-grade plastic (Chlorinated Polyvinyl Chloride) pipe commonly used for hot/cold water distribution, fire sprinkler piping, and some chemicals.

cUL (UL certifications for Canada): An independent testing laboratory that also provides full product listing and follow-up services.

Curtain Wall Joint: Perimeter gap between the concrete floor slabs and the exterior wall construction (usually of metal or glass) in high rise buildings.

Detail Drawing: An architectural drawing showing section details of a through-penetration firestop assembly with installation instructions and other pertinent details given.

DWV: Acronym for Drain, Waste, and Vent. Pipes that are used in plumbing applications.

Eccentric: Penetrating item that is offset to one side of a through-penetration hole such that the annulus varies around the penetrating item.

Elastomeric: A material having characteristics which allow it to expand or contract its shape and still return to its original dimensions without losing stability.

EMT (Electrical Metal Tubing): A thin wall galvanized steel pipe used to house electrical wiring or other types of conductive cables. Also commonly known as conduit.

Endothermic: A chemical reaction that allows materials to absorb heat.

F Rating: The time in hours that a firestop system will prevent the passage of flames through an opening, remain in place, and not permit the projection of a water stream through a fire rated assembly as determined by standard test methods ASTM E 814 or UL 1479.

Fill Material: Firestopping material used to fill within the penetration.

Fire Compartment of Fire Zone: An enclosed space in a building that is separated from all other parts of the building by the construction of Fire Separations having Fire Resistance Ratings.

Fire Resistive: Have a resistance to fire.

Fire Resistance Rating: Sometimes called fire rating, fire resistance classification, or hourly rating. A term defined in building codes, usually based on fire endurance required. Fire resistance ratings are assigned by building codes for various types of construction and occupancies, and are usually given in half-hour increments.

Fire-Retardant Barrier: A layer of material, which, when secured to a combustible material or otherwise interposed between the material and a potential fire source, delays ignition and combustion of the material when the barrier is exposed to fire.

Fire-Retardant Chemical: A chemical, which, when added to a combustible material, delays ignition and combustion of the resulting material when exposed to fire.

Fire-Retardant Coating: A fluid-applied surface covering on a combustible material that delays ignition and combustion of the material when the coating is exposed to fire.

5.11.0 A Glossary of Firestopping Terms (Continued)

Fire-Retardant Treatment: The use of a fire-retardant chemical or a fire-retardant coating.

Fire Risk: The probability that a fire will occur. The potential for risk to life or property.

Fire Separation: A construction assembly that acts as a barrier against the spread of fire.

Firestop System: A specific construction consisting of a fire rated assembly (wall or floor), penetrating item(s) (pipe, cable, etc.), and materials (sealant, backing material, etc.) that fill the opening around penetrating item(s) to prevent the spread of fire beyond the assembly for a specified period of time.

Fire Wall: 1. A wall constructed of solid masonry units, faced on each side with brick or reinforced concrete, used to subdivide a building or separate buildings, to restrict the spread of fire. 2. A wall with adequate fire resistance used to subdivide buildings to restrict the spread of fire.

Flame: A hot, usually luminous zone of gas, or particulate matter in gaseous suspension, or both, that is undergoing combustion.

Flame Front: The leading edge of a flame propagating through a gaseous mixture or across the surface of a liquid or solid.

Flame Resistance: The ability to withstand flame impingement or provide protection against it.

Flame-Resistant: Having resistance to flame.

Flame Spread Index: A number or classification showing a comparative measure derived from observations made during the progress of the boundary of a zone or flame under defined test conditions.

Flammable: Subject to easy ignition and rapid flaming combustion.

Flammable Vapor: The vapor given off by a flammable liquid at, and above, its flash point.

Flash Point: The lowest temperature of a sample at which application of an ignition source causes the vapor of a sample to ignite momentarily under specified conditions of test.

Glass Fiber Board: Fibrous glass insulation consisting of inorganic glass fibers formed into rigid boards using a binder.

Glow: 1. The visible light emitted by a substance because of its high temperature. 2. Visible light, other than from flaming, emitted by a solid undergoing combustion (TCG-01).
Gypsum Wallboard Type X: A mill fabricated product made of a gypsum core containing special minerals and encased in a smooth, finished paper on the face side and line paper on the back.

Heat Transmission Endpoint: An acceptance criterion of ASTM E 119 limiting the temperature rise of the unexposed surface temperature to an average of 250°F or a maximum of 325°F at any one point.

Hose Stream Test: A test of the physical integrity of an assembly after a specified period of burning in which it is removed from the furnace and exposed to a blast of water from a fireman's hose. ASTM E 119 specifies the nozzle size, pressure, duration, and distance from the assembly.

Ignition: The initiation of combustion.

Ignition Temperature: The lowest temperature at which sustained combustion of a material can be initiated under specified conditions.

Intumesce: To swell, enlarge, inflate, or expand with heat. Intumescent firestopping sealants swell when exposed to the intense heat of fire to close gaps or voids in through-penetration openings.

Joints: Gaps between two or more adjoining surfaces, left to provide for expansion and contraction of the assembly.

L Rating: An optional measurement of the rate of air leakage through a test sample, resulting from a specified air pressure difference applied across the surface of the test sample.

5.11.0 A Glossary of Firestopping Terms (Continued)

Lightweight Aggregate Concrete: Concrete made with aggregates of expanded clay, shale, slag or sintered slate or fly ash, and weighing 85 to 115 pcf.

Mineral Board: A rigid thermal insulation board consisting of either felted mineral fiber or cellular beads of expanded aggregate.

Mineral Wool or Rock Wool: High temperature resistant mineral fiber insulation used as fill material component in firestop systems to prevent the passage of flame.

Noncombustible: Will not combust; will not catch fire and burn

Normal Weight Concrete: Any concrete made with natural aggregates, cement and water having a unit weight of approximately 150 pcf.

Penetrant (Penetrating Item): Any item passing completely through a wall or floor, such as pipes, conduits, cables, etc.

Penetration: A void in a continual slab common to building through which penetrants may pass.

Point of Contact (Annular Space): When listed on UL system drawing, point at which penetrant touches the side of the opening.

PVC Pipe: Common plastic (Polyvinyl Chloride) pipe used for cold water distribution and drain, waste, and vent.

Pyrolysis: Irreversible chemical decomposition caused by heat, usually without combustion.

Safing Joint: The gap between the floor in a high-rise building and the curtain wall.

Sleeve: A liner, usually metallic, used to create an annulus for or around the penetrants. May be placed into concrete as it is poured or may be placed around a penetrant and inserted into a wall as it is erected.

Smoke: The airborne solid and liquid particulate and gases evolved when a material undergoes pyrolysis or combustion.

Smoke Seal: A seal that exhibits the ability to prevent passage of smoke and hot gases.

Smoldering: Combustion of a solid without flame, often evidenced by visible smoke.

Spontaneous Ignition: Initiation of combustion caused by internal, chemical exothermic reaction.

Sprayed Mineral Fiber: A blend of refined mineral fibers and inorganic binders. Water is added during the spraying operation; and the untapped unit weight is approximately 13 pcf.

Standard Fire Exposure: The time/temperature relationship defined by ASTM E 119.

Steel Deck Assembly: Otherwise known as fluted deck or floor pans, these floor assemblies consist of concrete that is poured into a corrugated steel pan assembly.

Surface Flame Spread: Surface flame spread per unit of time.

SWG: An abbreviation for Standard Wire Gauge usually used in combination with a number to identify a particular size wire.

System Number: A number assigned by listing organizations such as UL to a specific firestop detail or series of similar details. These details are then indexed in numerical order in a reference book or directory such as the UL Fire Resistance Directory.

T Rating: The time in hours required for the temperature on the unexposed surface of a fire rated assembly. A firestop system or any penetrating item to rise 325°F above the surrounding temperature as determined by standard test methods ASTM E 814 or UL 1479 (in addition to meeting F-Rating requirements).

Torr: A unit of pressure: 1 Torr = 1 mm Hg (Mercury) @ 1 degree Celsius.

5.11.0 A Glossary of Firestopping Terms (Continued)

Toxicity: A reflection of a material's ability to release poisonous particulate.

UL (Underwriters Laboratories Inc.): An independent testing laboratory that also provides full product listing and follow-up services.

UL 263: Standard Fire Test of Building Construction and Materials (UL equivalent to ASTM E 119).

UL 1479: "Fire Tests of Through-Penetration Firestops" (equivalent to ASTM E 814).

UL2079: "Tests for Fire Resistance of Building Joint Systems"

ULC (Underwriters Laboratories of Canada): An independent testing laboratory that also provides full product listing and follow-up services.

UL Fire Resistance Directory: A UL publication which contains test descriptions and ratings of firestop systems.

WHI (Warnock Hersey International, Inc.): An independent testing laboratory that also provides full product listing and follow-up services.

Wire Mesh: A galvanized steel hardware cloth used to support backing materials and sealants within the hollow core of gypsum wall and CMU construction.

Vented (Open) Piping System: Piping system which is vented to the atmosphere, to prevent backflow and vacuum, such as drains and vent pipes.

Zero Annular Space: A point of contact or an area where no gap exists between a penetrating item and the edge of the hole.

5.12.0 Definition of Sound

Sound is a pressure variation in air, water, or other fluid media, which may be detected by the human ear, presenting itself in "waves." Noise can be categorized as unwanted sound that may be hazardous to one's health or interferes with speech and verbal communication or is otherwise disturbing. Sound *amplitude,* which is the height of the sound wave from peak to valley, determines the loudness or intensity of sound; the wavelength determines the frequency, pitch, or tone of the sound.

5.12.1 Four Principal Methods Used in Soundproofing

- *Mass*—The more dense a structure is, the more difficult it will be for sound to penetrate. Adding an extra layer of drywall to a wood stud partition could result in an improvement of 4 to 5 dB.
- *Air barrier*—The airspace between partition walls adds to sound improvement. The sealed airspace in double-glazed windows will also decrease sound transmission.
- *Insulation*—Insulation in a wall cavity blocks the flow of sound but has no effect on structural noise such as vibration from equipment.
- *Mechanical decoupling*—Resilient channels on partitions prevent noise by isolating it, decreasing vibration, and increasing sound deadening. Isolation vibration bases for mechanical equipment are other examples of decoupling.

5.12.2 Four Acoustic Terms to Know

Four acoustic terms you need to be familiar with:

Reverberation
Reflections
Absorption—Noise Reduction Coefficient (NRC)
Isolation—Sound Transmission Class (STC)

Reverberation:



In an enclosed space, when a sound source stops emitting energy, it takes some time for the sound to become inaudible. This prolongation of the sound in the room caused by continued multiple reflections is called reverberation.

Reverberation time plays a crucial role in the quality of music and the ability to understand speech in a given space. When room surfaces are highly reflective, sound continues to reflect or reverberate. The effect of this condition is described as a live space with a long reverberation time. A high reverberation time will cause a build-up of the noise level in a space. The effects of reverberation time on a given space are crucial to musical conditions and understanding speech. It is difficult to choose an optimum reverberation time in a multi-function space, as different uses require different reverberation times. A reverberation time that is optimum for a music program could be disastrous to the intelligibility of the spoken word. Conversely, a reverberation time that is excellent for speech can cause music to sound dry and flat.

Reflections:



Reflected sound strikes a surface or several surfaces before reaching the receiver. These reflections can have unwanted or even disastrous consequences. Although reverberation is due to continued multiple reflections, controlling the Reverberation Time in a space does not ensure that the space will be free from problems from reflections.

Reflective corners or peaked ceilings can create a "megaphone" effect potentially causing annoying reflections and loud spaces. Reflective parallel surfaces lend themselves to a unique acoustical problem called standing waves, creating a "fluttering" of sound between the two surfaces.

Reflections can be attributed to the shape of the space as well as the material on the surfaces. Domes and concave surfaces cause reflections to be focused rather than dispersed which can cause annoying sound reflections. Absorptive surface treatments can help to eliminate both reverberation and reflection problems.

Noise Reduction Coefficient (NRC):
The Noise Reduction Coefficient (NRC) is a single-number index for rating how absorptive a particular material is. Although the standard is often abused, it is simply the average of the mid-frequency sound absorption coefficients (250, 500, 1000 and 2000 Hertz rounded to the nearest 5%). The NRC gives no information as to how absorptive a material is in the low and high frequencies, nor does it have anything to do with the material's barrier effect (STC).

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5.12.2 Four Acoustic Terms to Know (Continued)

Sound Transmission Class (STC):



The Sound Transmission Class (STC) is a single-number rating of a material's or assembly's barrier effect. Higher STC values are more efficient for reducing sound transmission. For example, loud speech can be understood fairly well through an STC 30 wall but should not be audible through an STC 60 wall. The rating assesses the airborne sound transmission performance at a range of frequencies from 125 Hertz to 4000 Hertz. This range is consistent with the frequency range of speech. The STC rating does not assess the low frequency sound transfer. Special consideration must be given to spaces where the noise transfer concern is other than speech, such as mechanical equipment or music.

Even with a high STC rating, any penetration, air-gap, or "flanking"path can seriously degrade the isolation quality of a wall. Flanking paths are the means for sound to transfer from one space to another, other than through the wall. Sound can flank over, under, or around a wall. Sound can also travel through common ductwork, plumbing, or corridors.

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5.12.3 Decibel—Unit of Measure for the Loudness or Strength of a Sound

What is Sound?

Sound is the vibration of the individual molecules of any substance. Sound vibrates in the air and moves through the substance like a wave, hence the term "sound wave". Three characteristics that define a sound wave are frequency, wavelength, and amplitude. We will look at these in depth in the following paragraphs. The only place in which sound can't travel is in a vacuum. Noise and sound are often used to mean the same thing and are measured in decibels.

Decibel

A decibel (dB) is a unit of measurement of the loudness or strength of a sound. The decibel was named after Alexander Graham Bell, and was originally created to measure cable and equipment performance. The lowest decibel level a human can hear is the zero point. A difference of 1 decibel is the minimum perceptible change in volume. An increase of 6 dB is a doubling of the volume. An increase of another 6 dB would again double the volume, so 12 dB is a four-fold volume increase. 18 dB is an eight-fold increase, etc. Section 5.12.4 is a list of examples of decibels.

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5.12.4 Typical Decibel Levels of Common Noises

0 dB	Threshold of hearing
20 dB	Buzzing insect at 1 metre
30 dB	Public library, whispering
40 dB	Household living room
50 dB	Light traffic, refrigerator
60 dB	Normal conversation, air conditioner
70 dB	Heavy traffic, busy restaurant
80 dB	Subway, noisy factory
90 dB	Lawnmower, large truck
100 dB	Chainsaw, jack hammer
120 dB	Rock concert
140 dB	Artillery fire, jet engine
180 dB	Rocket take-off

By permission, Soundsmart, CA.

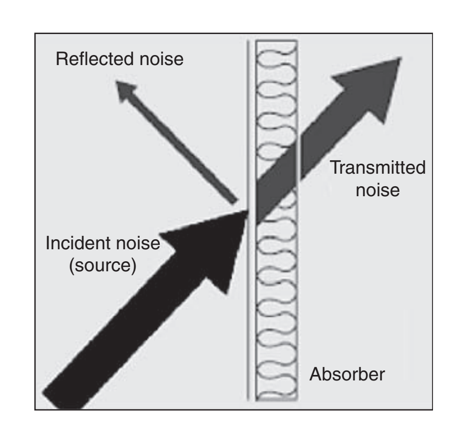
5.12.5 Comparative Examples of Noise Sources, Decibel Levels, and Their Effects

Noise Source	Decibel Level	Comment
Jet take-off (at 25 meters)	150	Eardrum rupture
Aircraft carrier deck	140	
Military jet aircraft take-off from aircraft carrier with afterburner at 50 ft (130 dB).	130	
Thunderclap, chain saw. Oxygen torch (121 dB).	120	Painful. 32 times as loud as 70 dB.
Steel mill, auto horn at 1 meter. Turbo-fan aircraft at takeoff power at 200 ft (118 dB). Riveting machine (110 dB); live rock music (108 -114 dB).	110	Average human pain threshold. 16 times as loud as 70 dB.
Jet take-off (at 305 meters), use of outboard motor, power lawn mower, motorcycle, farm tractor, jackhammer, garbage truck. Boeing 707 or DC-8 aircraft at one nautical mile (6080 ft) before landing (106 dB); jet flyover at 1000 feet (103 dB); Bell J-2A helicopter at 100 ft (100 dB).	100	8 times as loud as 70 dB. Serious damage possible in 8 hr exposure
Boeing 737 or DC-9 aircraft at one nautical mile (6080 ft) before landing (97 dB); power mower (96 dB); motorcycle at 25 ft (90 dB). Newspaper press (97 dB).	90	4 times as loud as 70 dB. Likely damage 8 hr exp
Garbage disposal, dishwasher, average factory, freight train (at 15 meters). Car wash at 20 ft (89 dB); propeller plane flyover at 1000 ft(88 dB); diesel truck 40 mph at 50 ft (84 dB); diesel train at 45 mph at 100 ft (83 dB). Food blender (88 dB); milling machine (85 dB);garbage disposal (80 dB).	80	2 times as loud as 70 dB. Possible damage in 8 hr exposure.
Passenger car at 65 mph at 25 ft (77 dB); freeway at 50 ft from pavement edge 10 a.m. (76 dB). Living room music (76 dB); radio or TV-audio, vacuum cleaner (70 dB).	70	Arbitrary base of comparison. Upper 70s are annoyingly loud to some people.
Conversation in restaurant, office, background music, Air conditioning unit at 100 ft	60	Half as loud as 70 dB. Fairly quiet
Quiet suburb, conversation at home. Large electrical transformers at 100 ft	50	One-fourth as loud as 70 dB.
Library, bird calls (44 dB); lowest limit of urban ambient sound	40	One-eighth as loud as 70 dB.
Quiet rural area	30	One-sixteenth as loud as 70 dB. Very quiet
Whisper, rustling leaves	20	
Breathing	10	Barely audible

modified from http://www.wenet.net/~hpb/dblevels.html] on 2/2000. Sources: Temple University Department of Civil/Environmental Engineering (www.temple.edu/departments/CETP/environ10.html), and Federal Agency Review of Selected Airport Noise Analysis Issues, Federal Interagency Committee on Noise (August 1992). Source of the information is attributed to Outdoor Noise and the Metropolitan Environment, M.C. Branch et al., Department of City Planning, City of Los Angeles, 1970.

5.13.0 Understanding Noise Control Product Types

ABSORBERS



Use: To reduce noise reflection. To dissipate noise energy.

Physical Properties: Porous, fibrous and sometimes covered with protective membranes. Noise enters the absorber and is partly dissipated (absorbed) within the material. Some is transmitted. Some is reflected. Absorber performance is expressed as a decimal value. A perfect absorber is rated at 1.00. The higher the decimal value the more effective the absorber will be.

Effectiveness is expressed as NRC (Noise Reduction Coefficient).

NRC: Percentage of acoustical energy absorbed calculated as an average of laboratory test data at several frequencies.

Noise Reduction Coefficients of Materials	NRC
Brick, unglazed	.05
Concrete block	.05
1/8" pile Carpet	.15
5/16" pile Carpet and foam	.35
Concrete floor	.00
Plaster, smooth finish	.05
Plywood paneling, 1/4" thick	.10
Water surface (as in swimming pool)	.00
1" thick fiberglass curtain	.70
4" thick smooth surface foam	.89
4" thick metal panel	.95

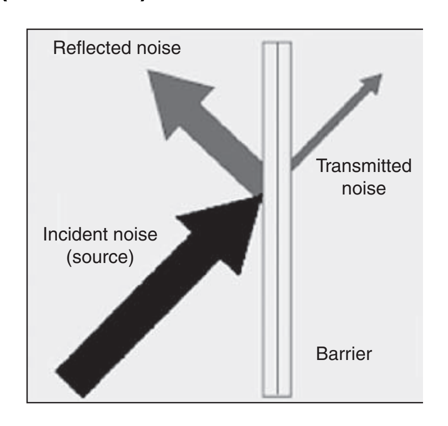
By permission, Industrial Noise Control, Inc., North Aurora, Illinois.

5.13.0 Understanding Noise Control Product Types (Continued)

BARRIERS

Use: To block transmission of noise.

Physical Properties: Non-porous, high density and usually non-fibrous. Barriers are generally flexible or damped. The noise is blocked, reflected and re-routed in another direction. Barrier materials are tested and rated for their Sound Transmission Loss capability. The number is stated in dB and the higher number signifies the better barrier. **Effectiveness** is expressed as STC (Sound Transmission Class).



STC: Single number rating derived from decibel loss data at several frequencies.

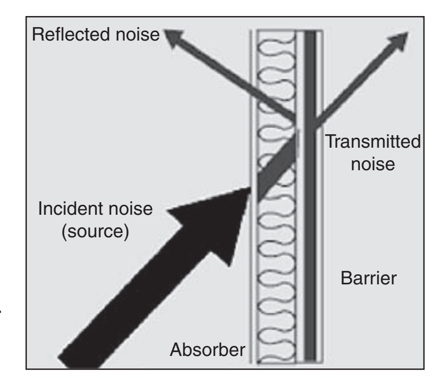
Sound Transmission Class of Materials	STC
1 lb. density barrier material	26
1 lb. density transparent curtain	26
5/8" Gypsum wallboard	30
3/16" Steel wall	31
2" fiberglass curtain with 1 lb. barrier	29
2" thick metal panel (solid and perforated)	35
4" thick metal panel (solid and perforated)	41
12" thick concrete	53
3/8" plasterboard	26
22 gauge steel	25
Solid core wood door, closed	27
Concrete block wall unpainted	44

COMPOSITES

Use: To block the transmission of noise and reduce reflections from the barrier.

Physical Properties: Consists usually of a layer of porous material and a layer of dense material. The composite material will have a performance capability as an absorber and as a barrier. Septum barriers are sandwiched between two absorber layers.

Effectiveness is a combination of STC and NRC ratings.



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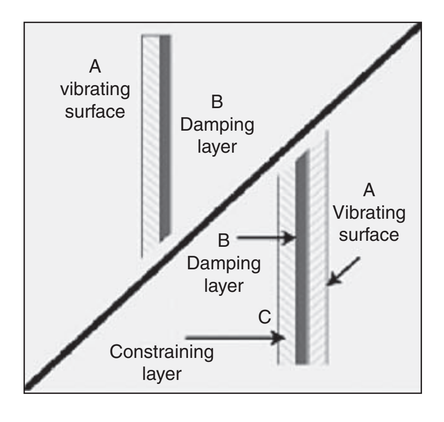
5.13.0 Understanding Noise Control Product Types (Continued)

DAMPING

Use: To reduce noise radiated from vibrating surfaces.

Physical Properties: Visco-elastic. Damping coatings take many forms. There are mastics for spraying, troweling, etc. and there are tapes and sheets with pressure sensitive adhesive. Damping treatments are sometimes combined with absorbers.

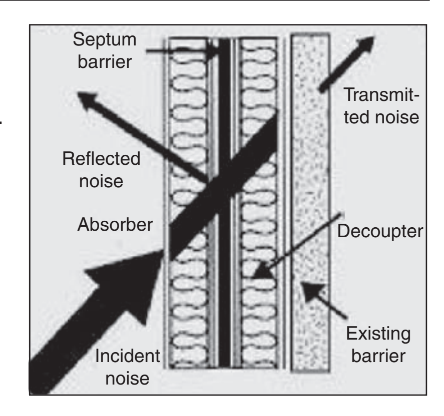
Effectiveness is expressed as a "loss factor" which is the damping/stiffness ratio of a material.



DECOUPLED COMPOSITES

Use: To enhance the performance of the composite material when applied to the inside of an existing barrier.

Decoupling creates an air space between the existing barrier and the septum composite barrier boosting transmission loss beyond what could be expected with direct attachment.



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5.13.1 Types of Noises

- *Airborne*—Traffic, voices, television that can penetrate walls, doors, open windows, HVAC ducts, and other imperfectly sealed wall and floor openings
- *Impact sounds*—Produced by falling objects or mechanical impacts
- *Structural vibration*—Created from vibrations emanating from HVAC equipment and/or plumbing fixtures

5.14.0 Noise Reduction Coefficient (NRC)—Recommended Sound Absorption Ratings for Various Building Types

With these caveats mentioned, the table below indicates NRC ratings for common building materials.

Material	NRC
Brick, painted	.00 - .02
Brick, unpainted	.00 - .05
Carpet, indoor-outdoor	.15 - .20
Carpet, heavy on concrete	.20 - .30
Carpet, heavy on foam rubber	.30 - .55
Concrete (smooth), painted	.00 - .05
Concrete (smooth), unpainted	.00 - .20
Concrete (block), painted	0.05
Concrete (block), unpainted	.05 - .35
Cork, floor tiles (3/4" thick)	.10 - .15
Cork, wall tiles (1" thick)	.30 - .70
Drapery, light weight (10oz.)	.05 - .15
Drapery, medium weight (14oz.), velour draped to half	0.55
Drapery, heavy weight (18oz.), velour draped to half	0.6
Fabric on Gypsum	0.05
Fiberglass, 3-1/2" batt	.90 - .95
Fiberglass, 1" Semi-rigid	.50 - .75
Glass	.05 - .10
Gypsum	0.05
Linoleum on Concrete	.00 - .05
Marble	0
Plaster	0.05
Plywood	.10 - .15
Polyurethane Foam (1" thick, open cell, reticulated)	0.3
Rubber on Concrete	0.05
Seating (occupied)	.80 - .85
Seating (unoccupied), metal	0.3
Seating (unoccupied), wood	0.3
Seating (unoccupied), fabric upholstered	0.6
Seating (unoccupied), leather upholstered	0.5
Soundboard (1/2" thick)	0.2
Sprayed Cellulose Fibers (1" thick on concrete)	.50 - .75
Steel	.00 - .10
Terrazzo	0
Wood	.05 - .15

5.15.0 Sound Transmission Coefficient (STC)—Ratings for Various Wall Assemblies

STC RATINGS FOR VARIOUS WALL ASSEMBLIES

Below are the STC ratings of various wall assemblies, each presented to help illustrate concepts, improvements, and rules of thumb. The estimated ratings are based on laboratory test results from various compendiums of STC ratings. It is recommended to consult a professional acoustician for more detailed information or to analyze the specifics of your project/assembly.

1. Insulation will noticeably improve the STC rating of an assembly.
2. Staggered or double stud walls are higher rated than single stud walls.
3. Metal stud walls perform better than wood stud walls.
4. Resilient channel can improve the STC rating of an assembly.
5. Adding additional layers of drywall can improve the STC rating of an assembly.
6. Drywall between double studs can dramatically reduce the STC rating of an assembly.

1. Insulation will noticeably improve the STC rating of an assembly.

Description	Estimated STC Rating	Wall Assembly
3 5/8" metal studs, 5/8" gyp (2 layers total), No insulation	38 - 40	
3 5/8" metal studs, 5/8" gyp (2 layers total), Batt insulation	43 - 44	

2. Staggered or double stud walls are higher rated than single stud walls.

Description	Estimated STC Rating	Wall Assembly
2x4 stud, 5/8" gyp (2 layers total), Batt insulation	34 - 39	
Staggered studs, 5/8" gyp (2 layers total), Batt insulation	46 - 47	
2x4 studs, 5/8" gyp (2 layers total), Batt insulation	56 - 59	

5.15.0 Sound Transmission Coefficient (STC)—Ratings for Various Wall Assemblies (Continued)

3. Metal stud walls perform better than wood stud walls.

(NOTE: This only applies to single stud assemblies. For double stud assemblies, there is virtually no difference.)

Description	Estimated STC Rating	Wall Assembly
2x4 stud, 5/8" gyp (2 layers total), Batt insulation	34 - 39	
3 5/8" metal studs, 5/8" gyp (2 layers total), Batt insulation	43 - 44	

4. Resilient channel can improve the STC rating of an assembly.

(NOTE: These ratings are based on laboratory tests. Because of the special care required when installing resilient channels, actual results could be substantially lower.)

Description	Estimated STC Rating	Wall Assembly
2x4 stud, 5/8" gyp (2 layers total), Batt insulation	34 - 39	
2x4 stud, 5/8" gyp (2 layers total), Resilient Channel, Batt insulation	45 - 52	

5. Adding additional layers of drywall can improve the STC rating of an assembly.

Description	Estimated STC Rating	Wall Assembly
2x4 stud, 5/8" gyp (2 layers total), Batt insulation	34 - 39	
3 5/8" metal studs, 5/8" gyp (3 layers total), Batt insulation	39 - 40	
2x4 stud, 5/8" gyp (4 layers total), Batt insulation	43 - 45	

5.15.0 Sound Transmission Coefficient (STC)—Ratings for Various Wall Assemblies (Continued)

6. Drywall between double studs can dramatically reduce the STC rating of an assembly.

Description	Estimated STC Rating	Wall Assembly
2x4 studs, 5/8" gyp (4 layers total), Batt insulation	44 - 45	
2x4 studs, 5/8" gyp (2 layers total), Batt insulation	56 - 59	
2x4 studs,5/8" gyp (3 layers total), Batt insulation	59 - 60	
2x4 studs, 5/8" gyp (4 layers total), Batt insulation	58 - 63	

5.15.1 STC Ratings for Masonry Walls

STC RATINGS FOR MASONRY WALLS

STC ratings for masonry/CMU walls is based on weight of the block and whether the cells are filled or not and what material it is filled with.

Estimated STC Ratings for CMU Walls

Wall Thickness, in.	Hollow Units		Grout Filled		Sand Filled	
	Weight	STC	Weight	STC	Weight	STC
4	20	44	38	47	32	46
6	32	46	63	51	50	49
8	42	48	86	55	68	52
10	53	50	109	60	86	55

The STC rating of a CMU wall can be estimated based on its weight using the following formula:

STC = 0.18W + 40

where W = pounds per square foot (psf)

Source: Stcratings.com.

5.15.2 STC Ratings and How They Impact Speech

STC RATINGS

25
Normal speech can be understood quite clearly.

30
Loud speech can be understood fairly well.

35
Loud speech audible but not intelligible.

42
Loud speech audible as a murmur.

45
Must strain to hear loud speech.

48
Some loud speech barely audible.

50
Loud speech not audible

Source: APA, The Engineered Wood Product.

5.15.3 Suggested STC Ratings for Various Types of Buildings

Table 4—Recommended Category Classification and Suggested Noise Criteria Range for Steady Background Noise as Heard in Various Indoor Functional Activity Areas.[1]

Type of Space	NC or RC Curve
1. Private residence	25 to 30
2. Apartments	30 to 35
3. Hotels/motels	
a. Individual rooms or suites	30 to 35
b. Meeting/banquet rooms	30 to 35
c. Halls, corridors, lobbies	35 to 40
d. Services/support areas	40 to 45
4. Offices	
a. Executive	25 to 30
b. Conference rooms	25 to 30
c. Private	30 to 35
d. Open-Plan areas	35 to 40
e. Computer/business machine areas	40 to 45
f. Public circulation	40 to 45
5. Hospitals and clinics	
a. Private rooms	25 to 30
b. Wards	30 to 35
c. Operating rooms	25 to 30
d. Laboratories	30 to 35
e. Corridors	30 to 35
f. Public areas	35 to 40
6. Churches	25 to 30[2]
7. Schools	
a. Lecture and classrooms	25 to 30
b. Open-Plan classrooms	30 to 35[2]
8. Libraries	30 to 35
9. Concert halls[2]	
10. Legitimate theaters[2]	
11. Recording studios[2]	
12. Movie theaters	30 to 35

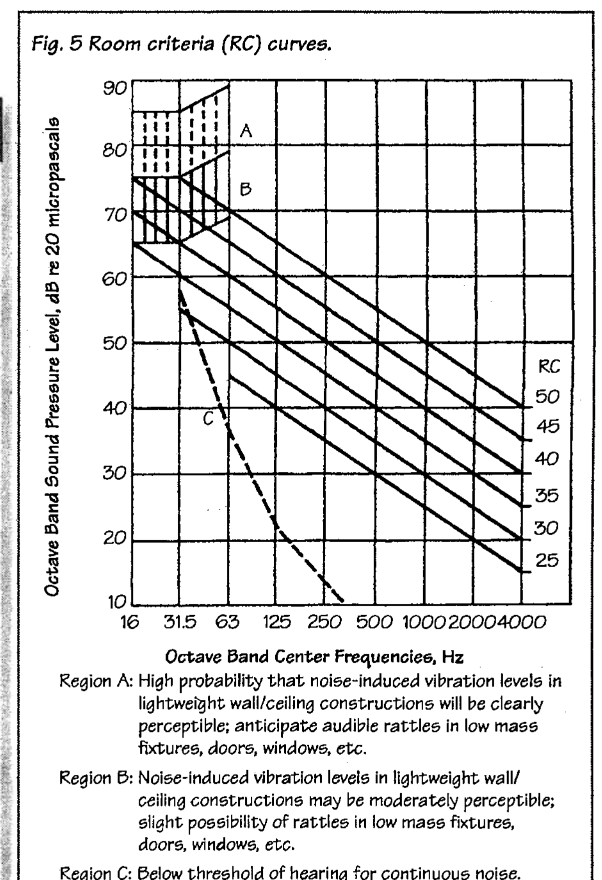
1 Design goals can be increased by 5 dB when dictated by budget constraints or when noise intrusion from other sources represents a limiting condition.

2 An acoustical expert should be consulted for guidance on these critical spaces.

STC, especially when traffic noise is the principal concern. The numeric value representation of OITC tends to be lower than the STC rating.

There are many options available for acoustical glazing, so it is important to make the right choice—especially if the building is exposed to significant exterior noise and the interior spaces are noise sensitive. The use of double-pane insulating glass is not adequate for many projects. Even single- or double-laminated insulating glass may not be adequate, especially at low outside temperatures, where regular PVB-laminated glass will yield a performance similar to that of non-laminated glass.

Fig. 5 Room criteria (RC) curves.



Region A: High probability that noise-induced vibration levels in lightweight wall/ceiling constructions will be clearly perceptible; anticipate audible rattles in low mass fixtures, doors, windows, etc.

Region B: Noise-induced vibration levels in lightweight wall/ceiling constructions may be moderately perceptible; slight possibility of rattles in low mass fixtures, doors, windows, etc.

Region C: Below threshold of hearing for continuous noise.

The sound-transmission loss through a door depends on the material and construction of the door and the effectiveness of the seal between the door and its frame. There is a mass law dependence of STC on weight (psf) for both wood and steel doors. The approximate relationships are:

For steel doors: $STC = 15 + 27 \log W$

For wood doors: $STC = 12 + 32 \log W$

where W = weight of the door, psf.

These relationships are purely empirical and a large deviation can be expected for any given door. ASTM E 1408 can be used to determine the acoustical performance of doors.

For best results, the distances between adjacent door and/or window openings should be maximized, staggered when possible, and held to a minimum area. Minimizing openings allows the wall to retain the acoustical properties of the precast concrete. The design characteristics of the door or window systems must be analyzed prior to specification. Such qualities as frame design, door construction, and glazing thickness are vital performance criteria. Installation procedures must be exact and care should be given to the framing of each opening. Gaskets, weatherstripping, and raised thresholds serve as both thermal and acoustical seals and are recommended.

5.15.4 Frequency, Wavelengths, and Amplitude

Frequency

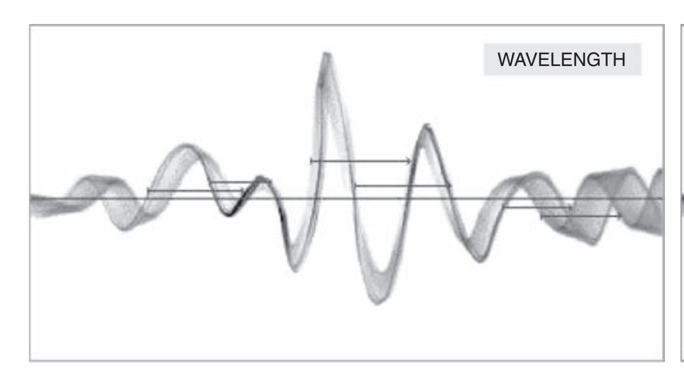
Frequency of sound means the number of vibrations or cycles per second a sound wave generates. A cycle is one complete rise and fall of pressure in the air through which a sound is passing. It is measured in hertz (Hz). The average human ear can detect a frequency between 20 and 20,000 Hz, or vibrations per second. Anything below 20 Hz is called infrasound, and above 20,000 is known as ultrasound. In general, younger people can hear lower frequencies of sound than older people. The pitch of sound, i.e. how high the note is, depends on the frequency of the wave. The higher the frequency, the higher the pitch, and vice versa.

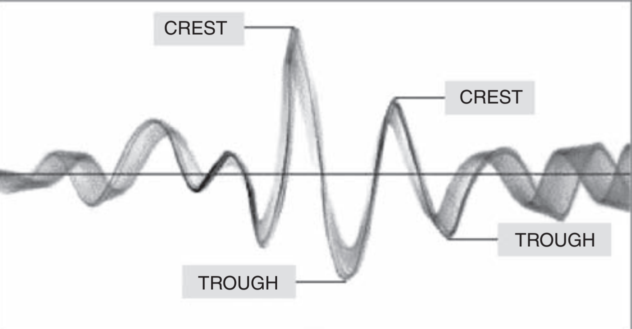
Dogs can detect frequencies as low as 67 Hz and as high as 45,000 Hz. Bats can detect frequencies as high as 10,000 Hz.

8 kHz
4 kHz
2 kHz
1 kHz
500 Hz
250 Hz
125 Hz

Wavelength

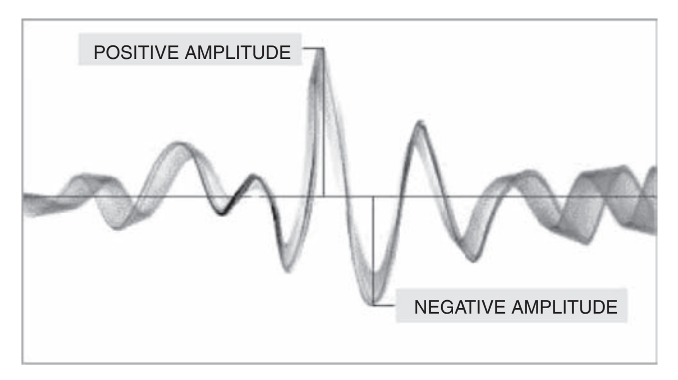
The wavelength is the horizontal distance between two successive points of a sound wave. The upper portion of the wave is called the crest, and the bottom is the trough.





Amplitude

The amplitude is the measure of the amount of energy in the sound wave, measured from the fixed point of the wave to the crest (positive amplitude) or to the trough (negative amplitude). With a loud sound there is more energy, hence the wave is higher. A softer sound produces a shorter wave.



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5.16.0 Acoustical Properties of Glass

Sound Transmission Class (STC)					
Type and Overall Thickness, in.	Inside Lite, in.	Construction Space, in.	Outside Lite, in.	STC	OITC
5/8 Insulated Glass	1/8	3/8	1/8	31	26
1/4 Plate or Float	—	—	1/4	31	29
1/2 Plate or Float	—	—	1/2	36	32
1 Insulated glass	1/4	1/2 Air space	1/4	35	28-30
1/4 Laminated	1/8	0.030 Vinyl	1/8	35	—
1 1/2 Insulated glass	1/4	9/16 Air space	3/16	37	28-30
3/4 Plate or Float	—	—	3/4	36	—
1 Insulated glass	1/4 Laminated	1/2 Air space	1/4	39	31
1 Plate or Float	—	—	1	37	—
2 3/4 Insulated glass	1/4	2 Air space	1/2	39	—
1 Laminated Insulated glass	1/4	1/2 Air space	1/8 plus 1/8	41	32

Transmission loss (dB)															
Frequency (Hz)															
125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
1/4 in. plate glass – 31 STC; 29 OITC															
25	25	24	28	26	29	31	33	34	34	35	34	30	27	32	37
1 in. insulating glass with 1/2 in. air space – 35 STC; 28 OITC															
24	29	22	22	25	30	33	35	38	40	42	42	37	37	43	46
1 in. insulating glass laminated with 1/2 in. air space – 39 STC; 31 OITC															
17	28	29	33	34	38	40	40	41	41	41	41	40	43	49	54

By permission, Industrial Noise Control, Inc., North Aurora, Illinois.

5.17.0 Plumbing Installation Acoustical Considerations

Sound paths
Water-resistant gypsum panels
Tile
Sealant
Sealant
Bathtub
Sealant
Sealant
Control joint in floor

Sealant at bathtub and floor; extend partition to floor; and insulation; add control joint (predesign detail)

Pack and sealant
Sleeve
Resilient material
Pack and sealant

Service penetration at edge of floating floor slab

THERMAFIBER sound attenuation blankets
Flanking sound path
THERMAFIBER sound attenuation blankets
Sealant

Continuous lightweight suspended ceiling

Flanking path

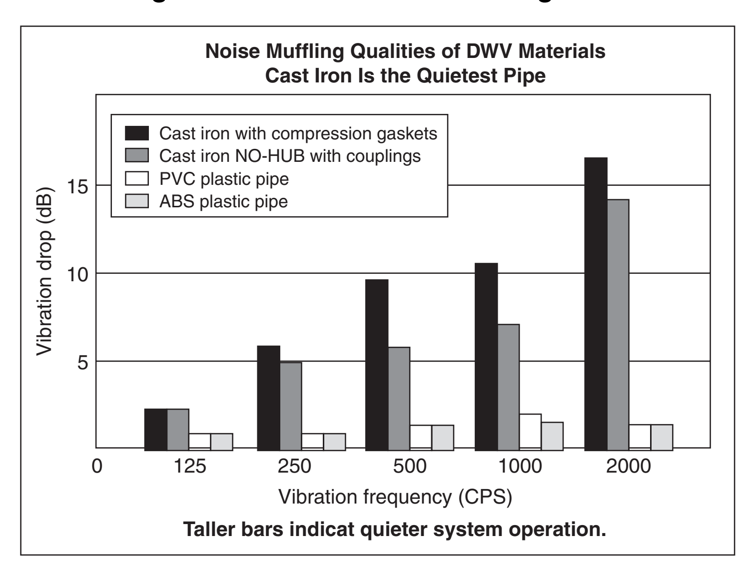
Structural floor slab

1/4" perimeter relief and sealant to prevent sound leaks
Structural interruption, sealant and gasket impedes structural flanking

Resilient pad in pipe hanger
Carrier
Well finish
Bolt with neoprene sleeve
Washer
Fixture
Neoprene washer
1/8" clearance
Pack and seal 1/4" joint (or use neoprene washer) at all wall penetrations
Support valve from fixture
Resilient support
Seal with acoustical sealant
1/4" neoprene at supports
Carner or "chair" must not short out floating floor.

Water closet insulation

5.17.1 Noise Muffling Qualities of Various Plumbing Riser Materials



Note: The higher the vertical axis value. The quieter the DWV system operates.
DWV = Drainage, Waste, and Vents

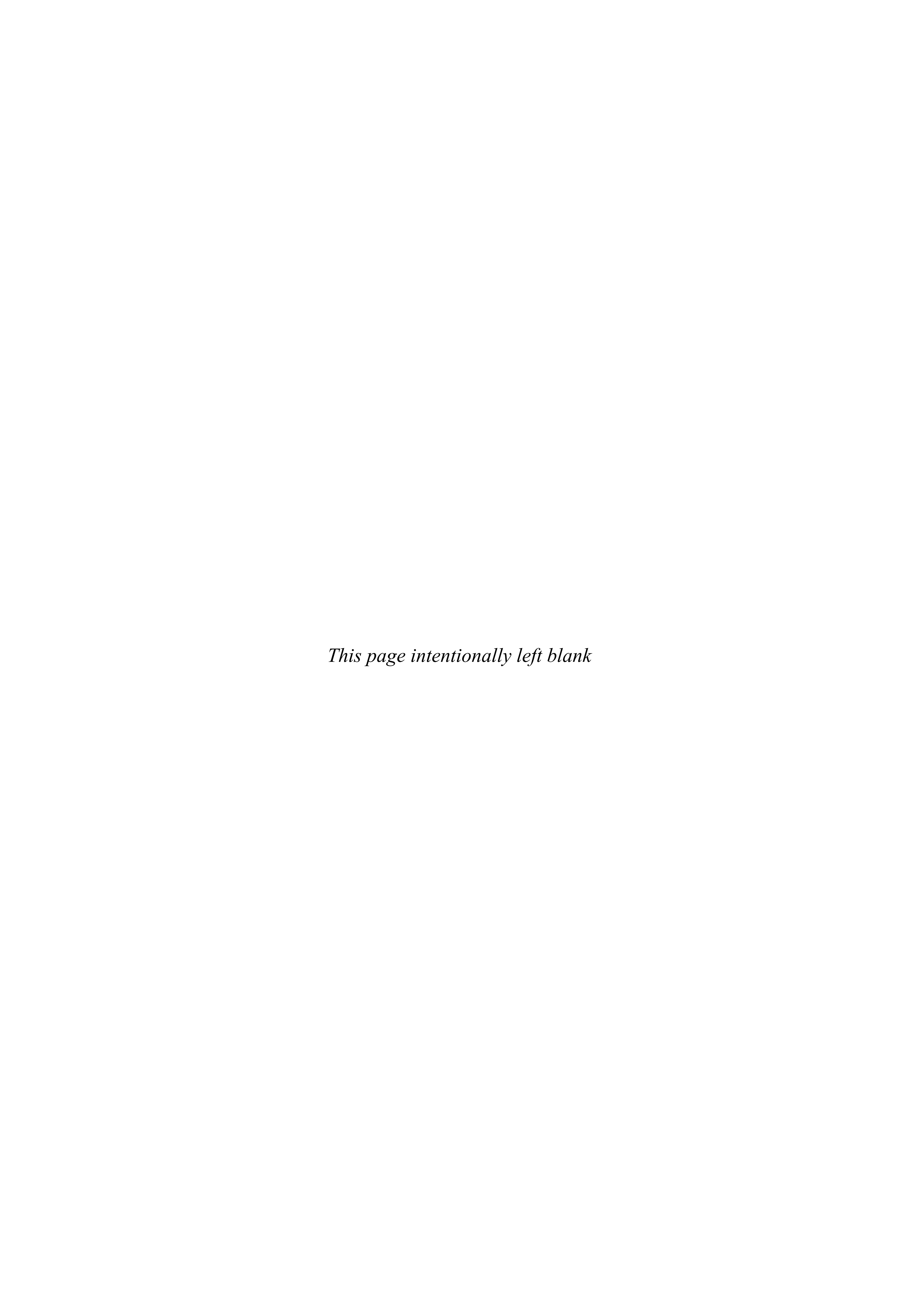
By permission, The Cast Iron Pipe Institute.

5.18.0 Duct System Installation Acoustical Considerations

Duct systems in both commercial and residential buildings can be constructed of metal or fiberglass, lined or wrapped with insulating materials. Not only is noise generated by the actual flow of air through the duct system, but noise is generated or can be controlled by the type of material from which the ductwork is constructed.

	Octave band frequency (Hz)					
Description	125	250	500	1000	2000	4000
Bare sheet metal*	0.1	0.1	0.1	0.1	0.1	0.1
Wrapped sheet metal*	0.2	0.2	0.2	0.2	0.2	0.2
Lined sheet metal* (one-inch thick)	0.3	0.7	1.9	5.3	4.8	2.3
Fiberglass duct (one-inch thick)	0.4	1.4	3.3	3.9	5.0	3.7

**1978 ASHRAE Transactions,* Vol. 84, Part 1, p. 122



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Section

6

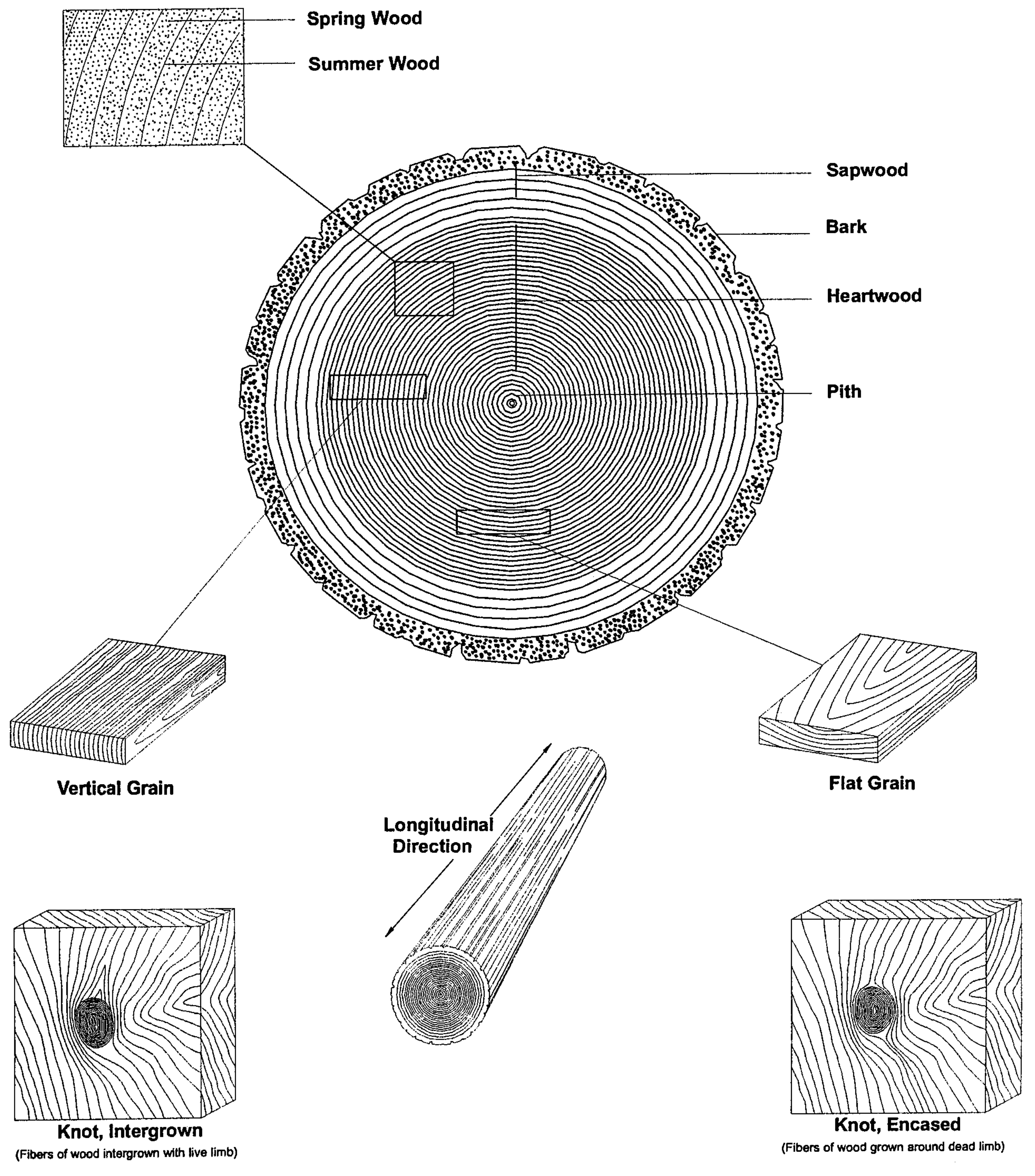
Interior Finishes—Millwork, Laminates, Paint, and Wall Coverings

Contents

6.0.0 Definition of Millwork

The wooden components of a building produced by machine are shown. Generally this is done off-site and includes items such as doors, window sash, trim, moldings, staircase, and cabinets.

6.1.1 A Tree's Anatomy



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6.1.2 Specific Gravity and Weight of Hardwoods

GUIDELINES TO SPECIFIC GRAVITY & WEIGHT OF HARDWOODS

SPECIES	SPECIFIC GRAVITY[1]	WEIGHT[2]
ALDER, RED Alnus rubra	.37	28
ASH, WHITE Average of 4 species	.54	41
ASPEN Populus tremuloides	.35	27
AVODIRE Turraeanthus africanus		36
BASSWOOD Tilia americana	.32	26
BEECH Fagus grandifolia	.56	45
BIRCH, SWEET Betula lenta	.60	46
BIRCH, YELLOW Betula alleghaniensis	.55	43
BUBINGA Guibourtia demeusil		55
BUTTERNUT Juglans cinerea	.36	27
CATALPA, NORTHERN Catalpa speciosa	.38	29
CATIVO Prioria copaifera	.40	29
CHERRY, BLACK Prunus serotina	.47	35
CHESTNUT Castanea dentata	.40	30
COTTONWOOD, EASTERN Populus deltoides	.37	28
CUCUMBER TREE, YELLOW Magnolia acuminata	.44	34
CYPRESS (BALD CYPRESS) Taxodium distichum	.42	32
DOGWOOD, FLOWERING Cornus florida	.64	51
EBONY (NIGERIAN) Diospyros crassiflora		63
ELM, AMERICAN Ulmlus Americana	.46	36
SWEETGUM (RED AND SAP) Liquidambar styraciflua	.44	34
TUPELO, WATER Nyssa aquatica	.46	35
HACKBERRY Celtis occidentalis	.49	37
HICKORIES, TRUE Average of 4 species	.65	51
HOLLY Ilex opaca	.50	40
LIMBA Terminalia superba	.45	34
LOCUST, BLACK Robinia pseudoacacia	.66	48
MAHOGANY, AFRICAN Khaya ivorensis	.43	31
MAHOGANY, CUBAN Swietenia mahogany	.57	41
MAHOGANY, CENTRAL AMERICAN Swietenia species	.45	32
MAKORE Tieghemella heckelii		40

SPECIES	SPECIFIC GRAVITY[1]	WEIGHT[2]
MAPLE, RED Acer rubrum	.49	38
MAPLE, SILVER Acer saccharinum	.44	33
MAPLE, SUGAR Acer saccharum	.57	44
MYRTLE Umbellularia Californica	.51	39
NARRA Pterocarpus indicus	.52	42
OAK, COMMERCIAL RED Average of 9 species	.56	44
OAK, COMMERCIAL WHITE Average of 6 species	.59	47
ORIENTAL WOOD Endiandro palmerstoni		44
OSAGE-ORANGE Maclura pomifera	.76	
PADUAK (AFRICAN) Pterocarpus soyauxii		43
PADUAK (ANDAMAN) Pterocarpus dalbergioides	.62	45
PADUAK (BURMA) Pterocarpus macrocarpus	.75	54
PALDAO Dracontomelum dao	.59	44
PECAN Carya illinoensis	.60	47
PEARWOOD (EUROPEAN) Purus communis		43
PHILIPPINE HARDWOODS		
RED LAUAN Shorea negrosensis	.40	36
WHITE LAUAN Pentacme contorta		36
TANGUILE Shorea polysperma	.53	39
POPLAR, YELLOW (TULIPTREE) Liriodendron tulipifera	.38	28
PRIMAVERA Cybistax donnell-smithii	.40	30
ROSEWOOD (BRAZIL) Dalbergia nigra		50
SAPELE Entandrophragma cylindricum	.54	40
SATINWOOD (EAST INDIAN) Chloroxylon swientenio	.83	67
SONORA (MANGGASINORO) Shorea philippinensis	.42	31
SYCAMORE Platanus accidentalis	.46	35
TEAK Tectona grandis	.60	43
TIGERWOOD Lavoa klaineana	.45	34
WALNUT, AMERICAN (BLACK) Juglans nigra	.51	39
WILLOW, BLACK Salix nigra	.34	26
ZEBRAWOOD Microberlinia brazzavillensis	.62	48

The data for native species as furnished on this chart are from the U.S. Forest Products Laboratory's Technical Bulletin 158.

1 (Based on green volume & oven dry weight)

2 (Based on pounds per cubic foot at 12% moisture content)

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6.1.3 Sizes of Finish Lumber

SIZES OF FINISH LUMBER

FINISH DIMENSIONS RELATE TO S4S AND PATTERN MEMBERS, ALLOW 1/32" FOR MACHINE SANDING.

NOMINAL (ROUGH) THICKNESS	FINISH (S4S) THICKNESS	NOMINAL (ROUGH) WIDTH	FINISH (S4S) WIDTH
1" (4/4)	11/16"	1"	11/16"
1-1/4" (5/4)	15/16"	2"	1-1/2"
1-1/2" (6/4)	1-3/16"	3"	2-1/2"
2" (8/4)	1-1/2"	4"	3-1/2"
2-1/2" (10/4)	2"	5"	4-1/4"
3" (12/4)	2-1/2" *	6"	5-1/4"
4" (16/4)	3-1/2" **	8"	7"
	* Honduras Mahogany subject to availability and glue-up	10"	9"
	** Not applicable to hardwoods	12"	11"
		Over 12"	1" Less

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6.1.4 Veneer Cut—Rotary, Plain Sliced, Quarter Sliced, Rift-Cut

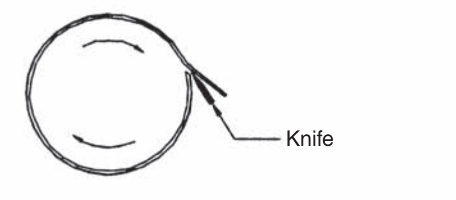
TYPES OF VENEER CUTS

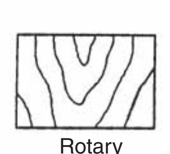
4.1 The manner in which veneers are cut is an important factor in producing the various visual effects obtained. Two woods of the same species, but with their veneers cut differently, will have entirely different visual character even though their color values are similar.

4.2 In plywood manufacture, the principal methods of cutting veneers are used, depending on the type of veneer required (whether for face, crossband, or core), the nature of the log, and the veneer figure desired. Primarily the veneer slicer and veneer lathe are the equipment employed. The methods are:

4.2.1 **ROTARY**

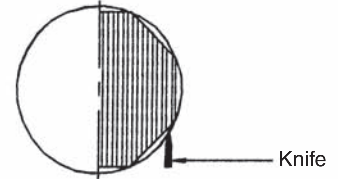
4.2.1.1 The log is mounted centrally in the lathe and turned against a razor sharp blade, like unwinding a roll of paper. Since this cut follows the log's annular growth rings, a bold variegated grain marking is produced. Rotary cut veneer is exceptionally wide.

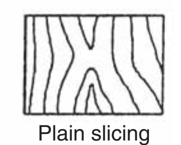



Rotary

4.2.2 **PLAIN-SLICING (OR FLAT-SLICING)**

4.2.2.1 The half log is mounted with the heart side float against the guide plate of the slicer and the slicing is done parallel to a line through the center of the log. This produces a variegated figure.



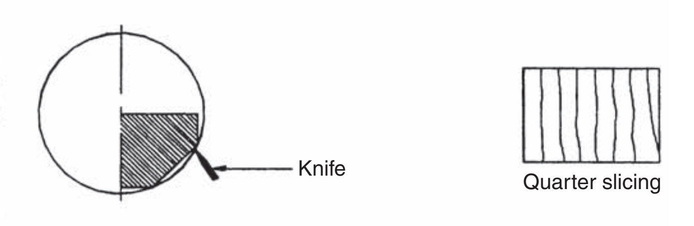

Plain slicing

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6.1.4 Veneer Cut—Rotary, Plain Sliced, Quarter Sliced, Rift-Cut (Continued)

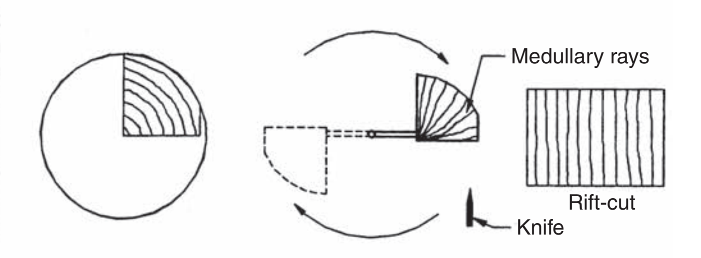
4.2.3 **QUARTER-SLICING**

4.2.3.1 The quarter log is mounted on the guide plate so that the growth rings of the log strike at approximately right angles, producing a series of stripes, straight in some woods varied in others. No limitations on the amount of medullary ray in oak.



4.2.4 **RIFT-CUT HARDWOOD OR VERTICAL GRAIN CUT SOFTWOOD**

4.2.4.1 **RIFT-CUT** veneer is produced in the various species of Oak. Oak has medullary ray cells which radiate from the center of the log like the curved spokes of a wheel. The rift or comb grain effect is obtained by cutting perpendicular to these medullary rays either on the lathe or slicer. Comb grain is selected from rift. Medullary ray flake is limited.



4.2.4.2 **VERTICAL GRAIN** cut is produced in Douglas Fir and Redwood. The vertical grain effect is produced by cutting perpendicularly to the growth rings.

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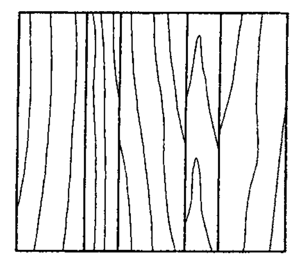
6.1.5 Veneer Panel Matching

VENEER MATCHING WITHIN A PANEL FACE

5.1 Just as the different veneer cutting methods can alter grain characteristics, matching can alter the appearance or match of a given panel or an entire installation. There is a wide choice in the types of matches available in hardwoods and basically the method of cutting has no bearing in matching. As a log segment is cut, the thin pieces of veneer are retained in perfect sequence. This yield of veneer from a single log is known as a flitch. All the veneers in this flitch are kept in sequence. The joining of the veneers is accomplished by means of a "tapeless splicer" which glues the long edges of the veneers together in whatever pattern is to be used. The panels thus formed from this particular flitch, or log yield, are kept together in sequence.

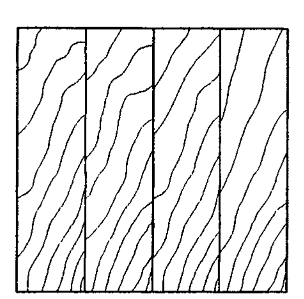
5.1.1 **RANDOM-MATCHING**

5.1.1.1 Veneers are joined with the intention of creating a casual unmatched effect. Veneers from several logs may be used in the manufacturing of a set of panels.



5.1.2 **SLIP-MATCHING**

5.1.2.1 In slip-matching, the veneer leaves are matched together, side by side, as they are taken in sequence from the flitch, so that the pieces are not matched for color or grain at the joints. This method of matching repeats the same flitch characteristics from piece to piece. Since all individual pieces are matched exactly the same in regards to loose or tight side up, slip matching eliminates the color shading normally associated with book-matching. Some species of hardwood do not blend into this pattern.



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6.1.6 Casework and Veneer Adhesive Types and Characteristics

GUIDELINES TO ADHESIVES

ADHESIVE:

PERFORMANCE TEST:

Type I-Fully Waterproof (Exterior)	2 Cycle Boil/Shear Test
Type II-Water Resistant (Interior)	3 Cycle Soak Test
Type III-Water Resistant (Interior)	2 Cycle Soak Test

GENERIC NAME	USED FOR BONDING	ANSI/HPVA NWWDA -I.S.	CHARACTERISTICS
1. **Aliphatic** (Carpenter's Glue)	Wood and wood products	Type II	Non-toxic; non-flammable; non-staining; water resistant; **NOT** waterproof.
2. **Casein**	Wood and wood products	Type II	Highly water resistant; **NOT** waterproof.
3. **Contact Cement**	Plastic laminates and veneers to wood	Type II	Highly water resistant; **NOT** waterproof.
4. **Epoxy**	Wide range; wood; wood to metals	Type I	Two-part glue--formulas vary; completely waterproof.
5. **Hot-melt Glue**	Wide range; bonds wood to vinyl, metal and wood	Not tested for moisture resistance	Liquefies when heated; bonds in a liquid state; solidifies as it cools. Used extensively for edge banders and other automatic equipment.
6. **Polyvinyl Acetate** PVA	Wood and wood products	Slight moisture resistance	Good for cabinet work and interior woodwork. **NOT** recommended for joints with sustained loads.
7. **Polyvinyl Acetate** PVA Catalyzed	Wood and wood products	Type I	Used for assembly gluing where exterior waterproof bonds are required.
8. **Polyvinyl Chloride** PVC	Wide variety of materials	Not tested for moisture resistance	Crystal clear; fast drying.
9. **Resorcinol Resin**	Wood, wood products and laminates	Type I	Fully waterproof; purple glue line; two parts--liquid resin and powdered catalyst. Pot life-3 hours.
10. **Urea Resin**	Wood and wood products	Type II	Plastic resin glue; mixed with water; excellent for cabinet work; must be clamped. Drying time 3 - 7 hours at 70° F.
11. **Panel / Construction Adhesive**	Metal to wood, particleboard, or plywood; also plastic surfaces	Type II	Plastic epoxy base; liquid state; dries fast; very difficult to remove. Can be used to permanently set adjustment screws in European type hinges.

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6.2.0 Moldings and Trim



Casings & Baseboards

ALL SIZES NOMINAL

001		BDL
7/16" x 2-3/16"	Hemlock	10

010		BDL
7/16" x 1-1/2"	Hemlock	20

493		BDL
1/2" x 2-1/4"	Hemlock	10

473		BDL
5/8" x 2-1/4"	VG Fir	8
9/16" x 2-1/4"	LDF Primed	6

041		BDL
7/16" x 2-1/4"	Hemlock	10

3014		BDL
7/16" x 2-3/16"	Hemlock	10

3102		BDL
7/16" x 3-1/4"	Hemlock	10

492		BDL
1/2" x 2-1/2"	Ultralite	10

472		BDL
9/16" x 2-1/2"	Ultralite	10
5/8" x 2-1/2"	Hemlock	1
5/8" x 2-1/2"	VG Fir	1

494		BDL
1/2" x 3-1/4"	Ultralite	10

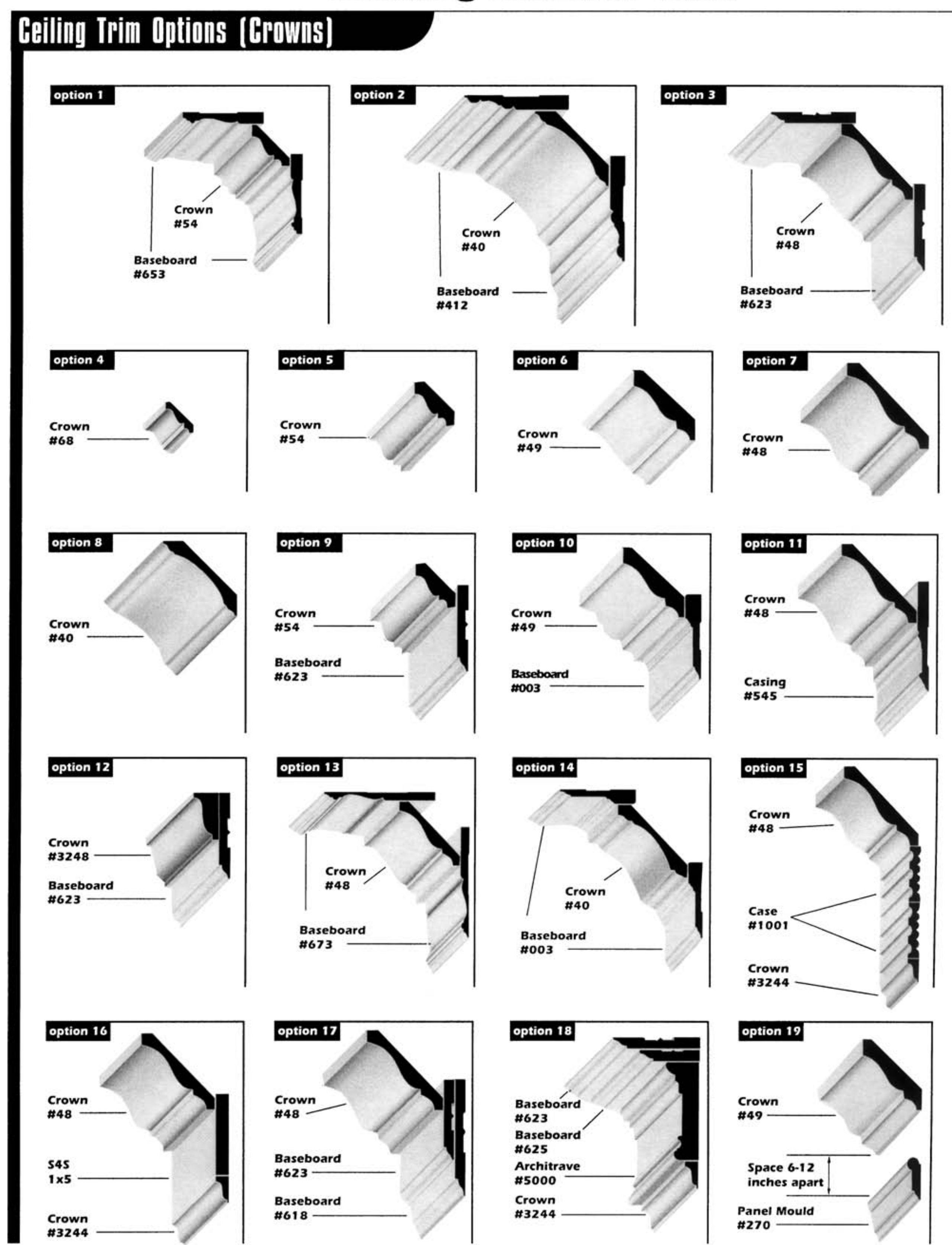
495		BDL
5/8" x 3-1/2"	Hemlock	1
5/8" x 3-1/2"	VG Fir	1
11/16" x 3-1/2"	LDF Primed	1

3112		BDL
3/8" x 3-1/4"	Hemlock	10
1/2" x 3-1/4"	VG Fir	10
1/2" x 3-1/4"	LDF Primed	6

669		BDL
7/16" x 5-1/2"	Hemlock	1

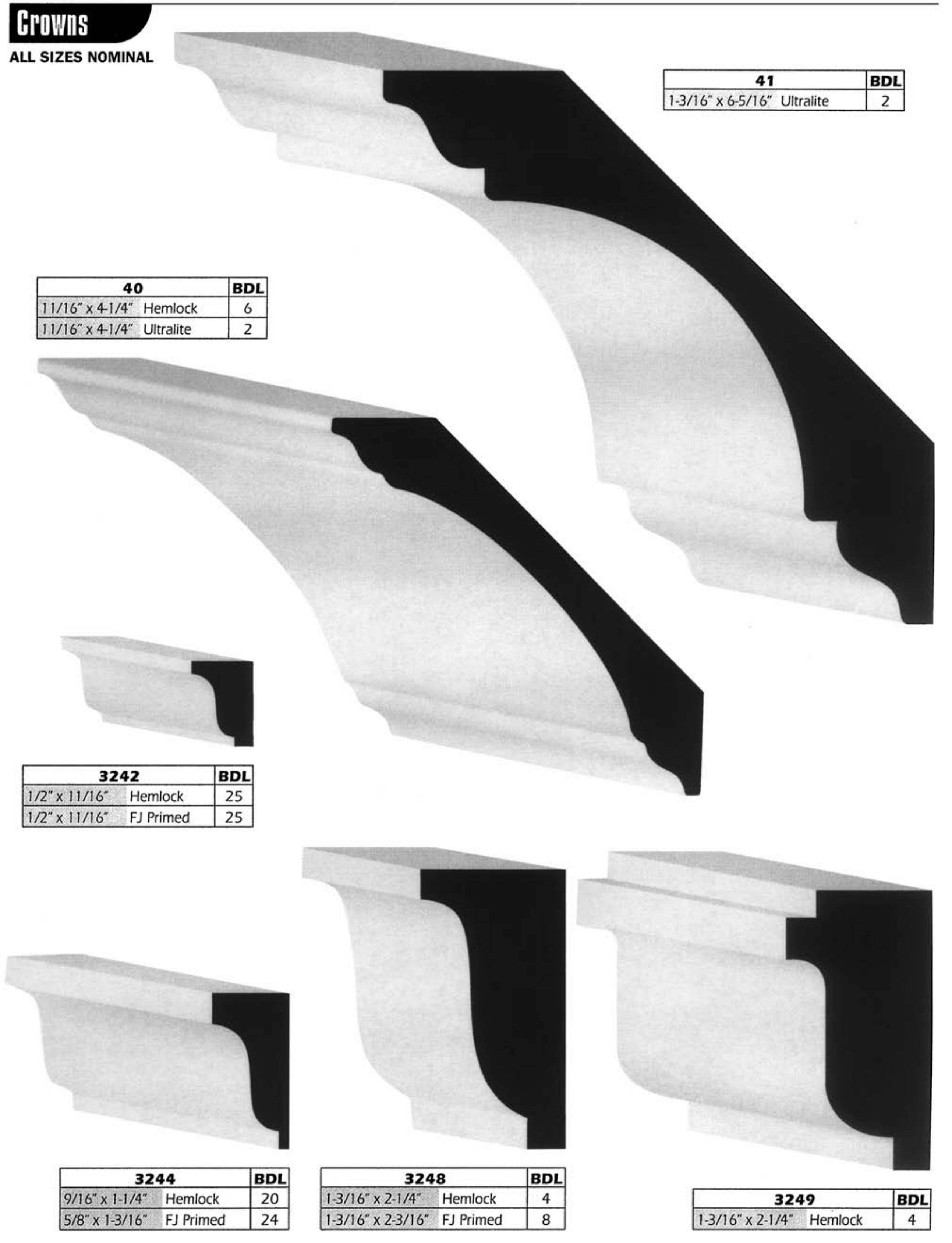
By permission, Architectural Millwork Manufacturing Co., Eugene, Oregon.

6.2.0 Moldings and Trim (Continued)



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6.2.0 Moldings and Trim (Continued)



41		BDL
1-3/16" x 6-5/16"	Ultralite	2

40		BDL
11/16" x 4-1/4"	Hemlock	6
11/16" x 4-1/4"	Ultralite	2

3242		BDL
1/2" x 11/16"	Hemlock	25
1/2" x 11/16"	FJ Primed	25

3244		BDL
9/16" x 1-1/4"	Hemlock	20
5/8" x 1-3/16"	FJ Primed	24

3248		BDL
1-3/16" x 2-1/4"	Hemlock	4
1-3/16" x 2-3/16"	FJ Primed	8

3249		BDL
1-3/16" x 2-1/4"	Hemlock	4

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6.2.0 Moldings and Trim (Continued)

Moulding Selection Guide

Panel Moulds

ALL SIZES NOMINAL

3277		BDL
3/8" x 3/4"	FJ Primed	25

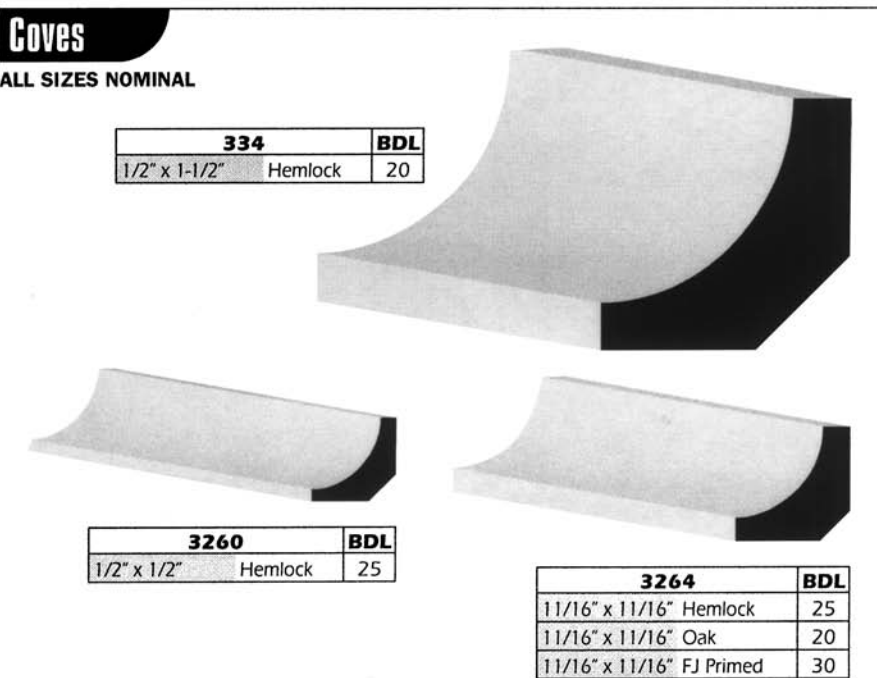
3278		BDL
3/8" x 1-1/8"	FJ Primed	25

22 Shadow Box		BDL
1/2" x 1"	Hemlock	20
1/2" x 1"	FJ Primed	20

704		BDL
5/8" x 5/8"	Hemlock	10

270 Picture Mould		BDL
11/16" x 1-3/4"	Hemlock	12

703		BDL
7/16" x 3/4"	Hemlock	10



Coves

ALL SIZES NOMINAL

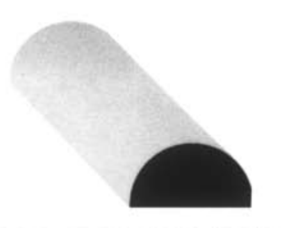
334		BDL
1/2" x 1-1/2"	Hemlock	20

3260		BDL
1/2" x 1/2"	Hemlock	25

3264		BDL
11/16" x 11/16"	Hemlock	25
11/16" x 11/16"	Oak	20
11/16" x 11/16"	FJ Primed	30



ALL SIZES NOMINAL



3212		BDL
3/8" x 3/4"	Hemlock	25



3202		BDL
1/2" x 1/2"	Hemlock	25
1/2" x 1/2"	Oak	20

3200		BDL
1/4" x 1/4"	Hemlock	25

3206		BDL
11/16" x 11/16"	Hemlock	25
11/16" x 11/16"	Oak	20
11/16" x 11/16"	FJ Primed	30



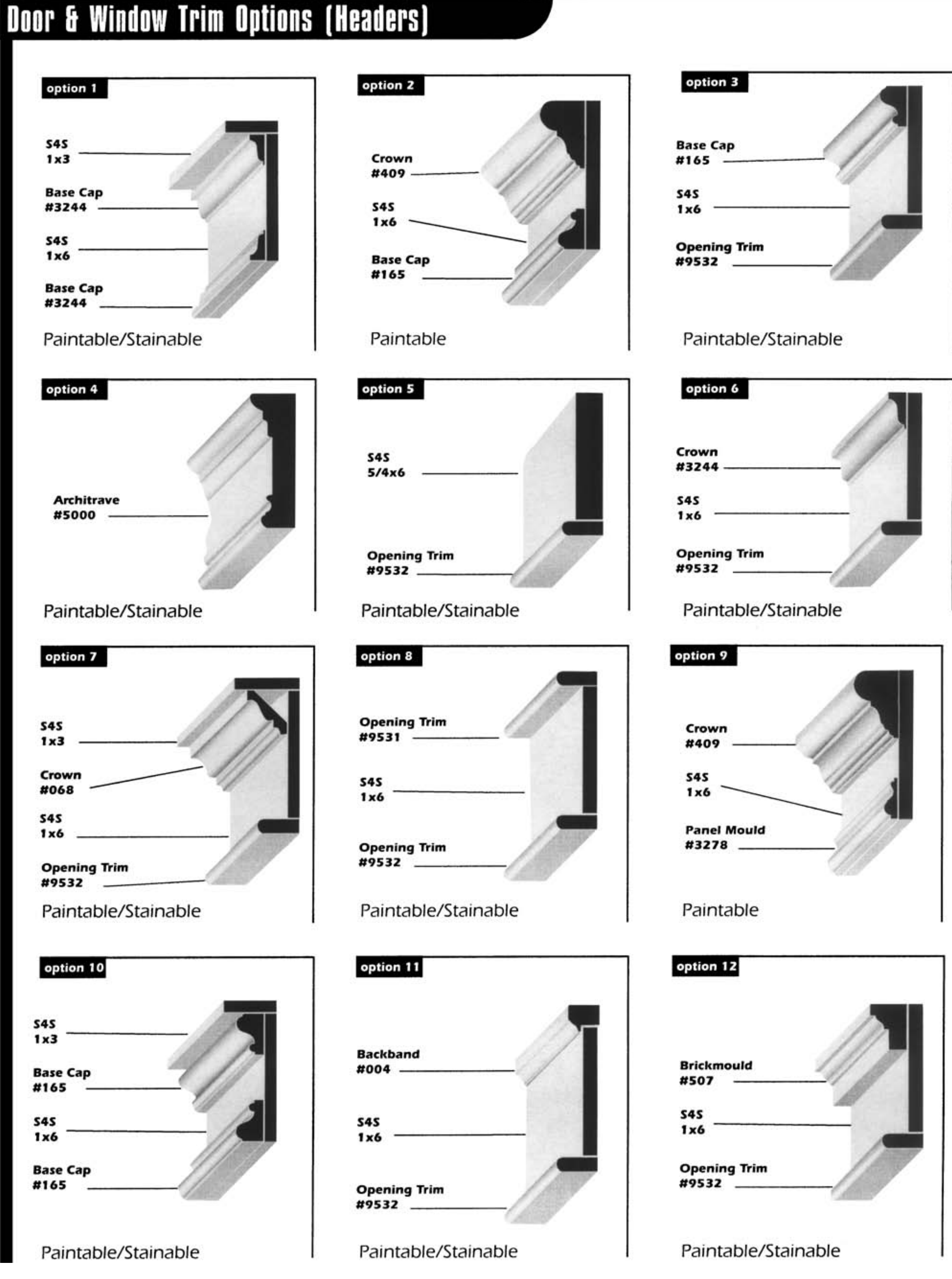
3222		BDL
11/16"	Hemlock	25

3224		BDL
1-1/16"	Hemlock	10

3226		BDL
1-5/16"	Hemlock	10

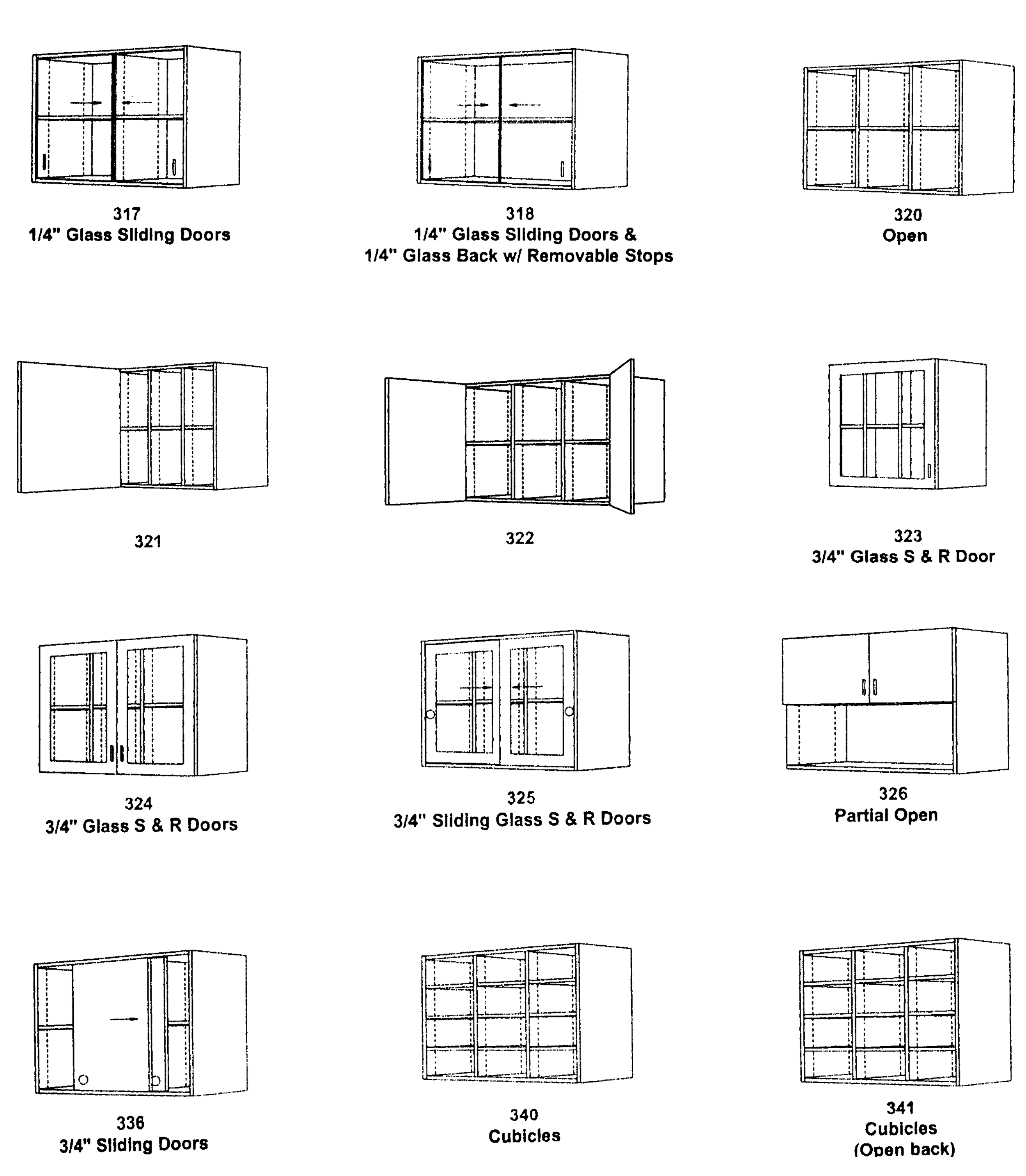
3228		BDL
1-1/2"	Hemlock	10

6.2.0 Moldings and Trim (Continued)



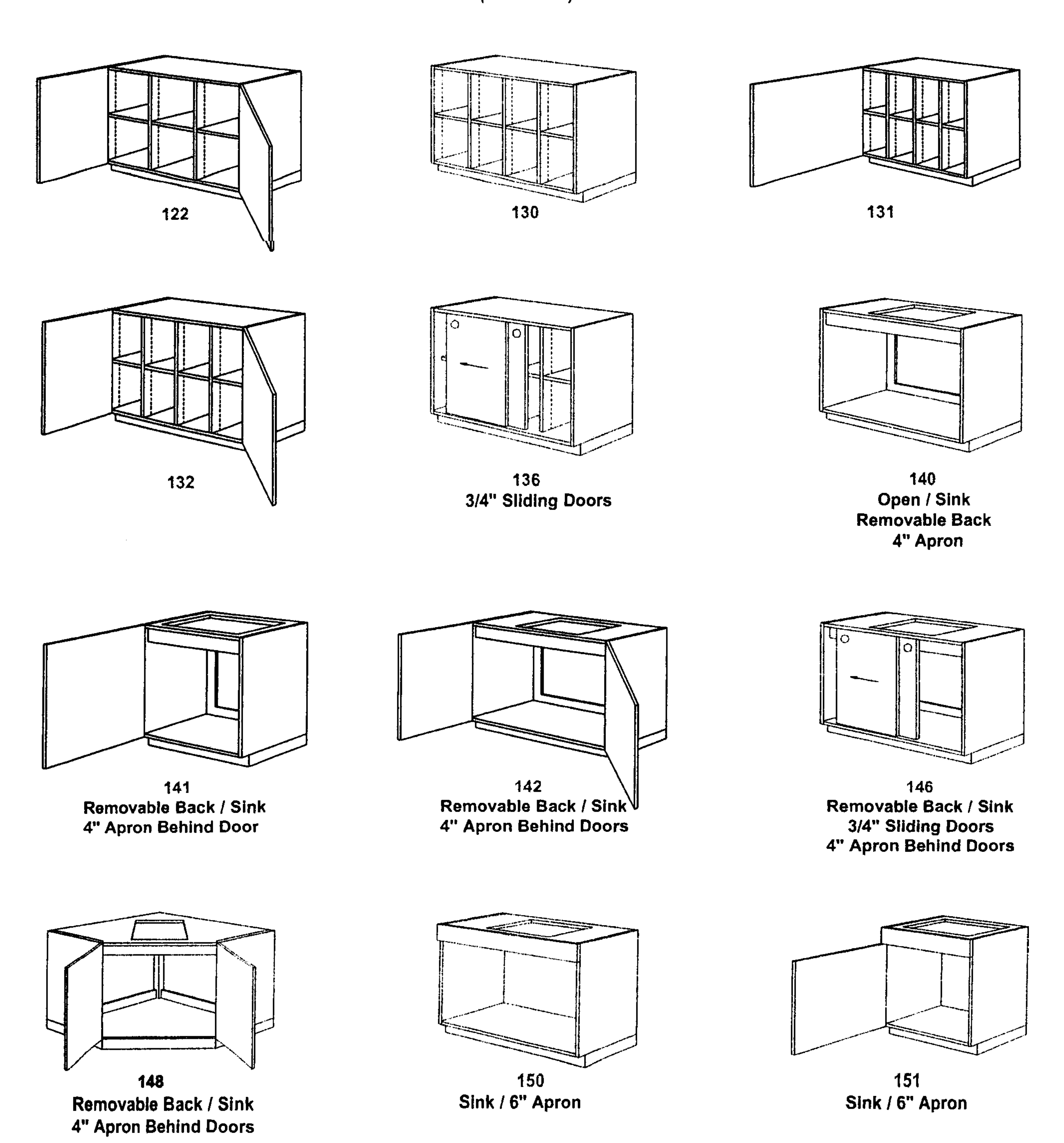
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6.3.0 Cabinetry—Wall-Hung Cabinets and Base Cabinets



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6.3.0 Cabinetry—Wall-Hung Cabinets and Base Cabinets (Continued)



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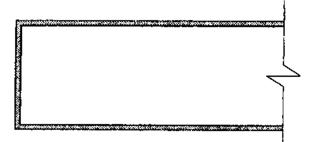
6.3.1 Cabinet Door Types and Vertical Meeting Edge Details

1.10 **CABINET DOOR TYPES** (Edge-banding is not required with SPC)

NOTE: Profiles shown are for illustration purposes only and are not intended as design criteria.

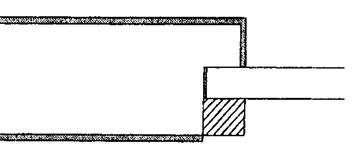
1.10.1 **FLUSH CABINET DOORS**

1.10.1.1 **TYPE A** Edge-banding required.

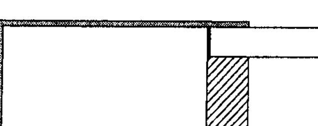


1.10.2 **STILE and RAIL CABINET DOORS**

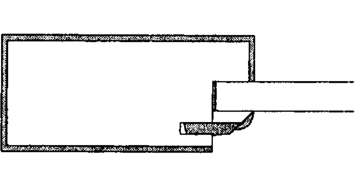
1.10.2.1 **TYPE B** Edge-banding required.
Wood or synthetic stops required.



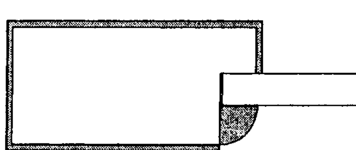
1.10.2.2 **TYPE C** Edge-banding required.
Minimum 0.048" thick HPL required on face.
Wood or synthetic stops required.



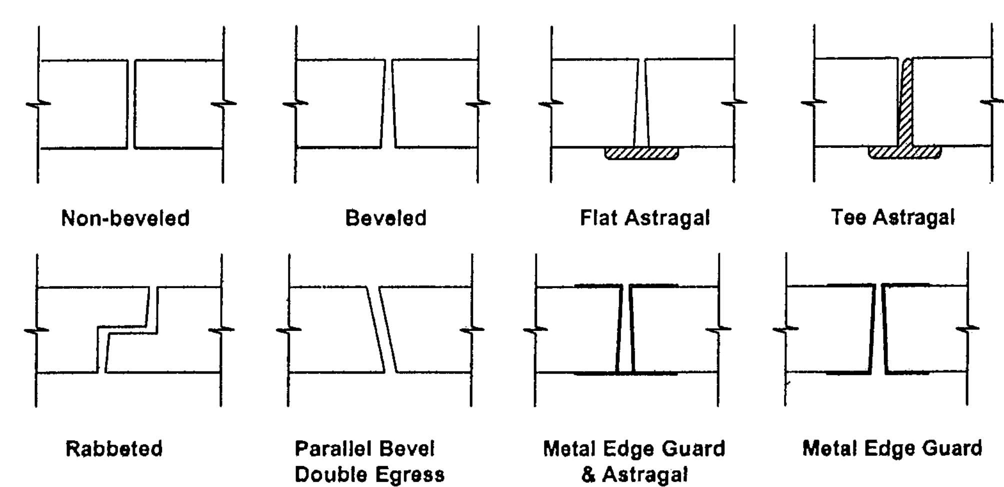
1.10.2.3 **TYPE D** Synthetic retainer.



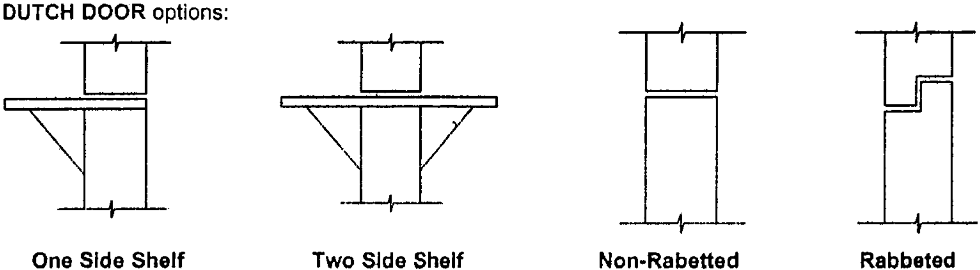
1.10.2.4 **TYPE E** Synthetic retainer.



1.15 **VERTICAL MEETING EDGE** options:

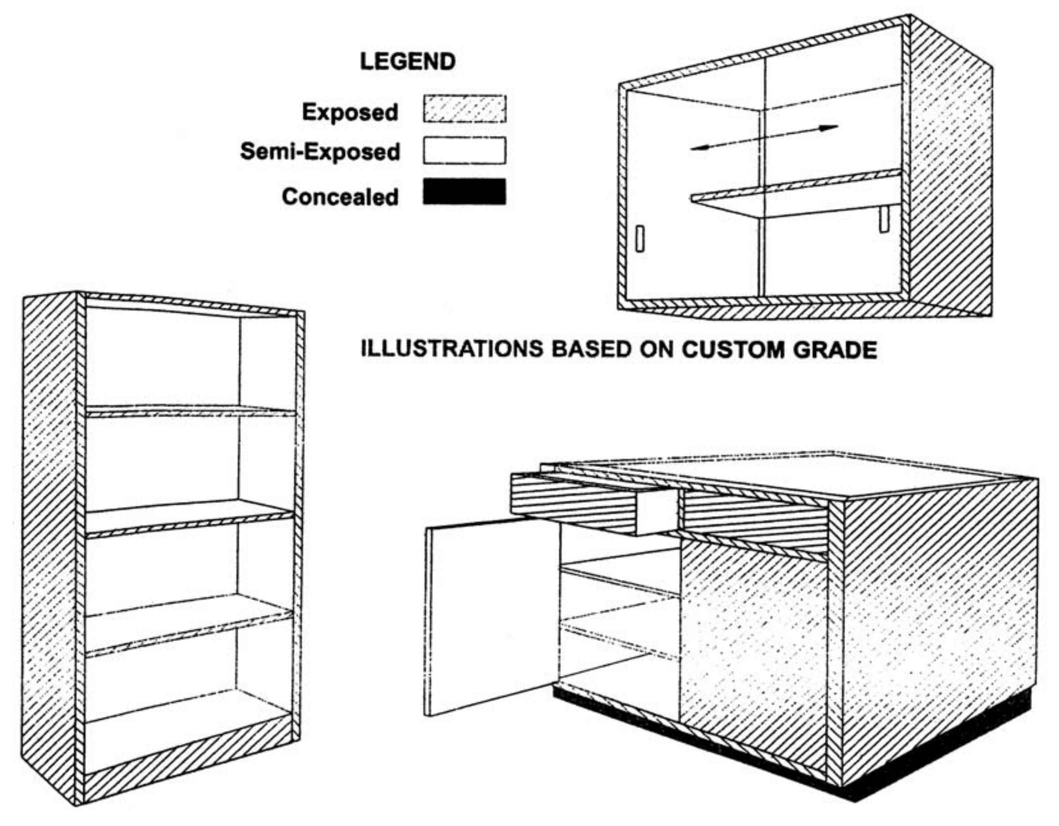


1.16 **DUTCH DOOR** options:



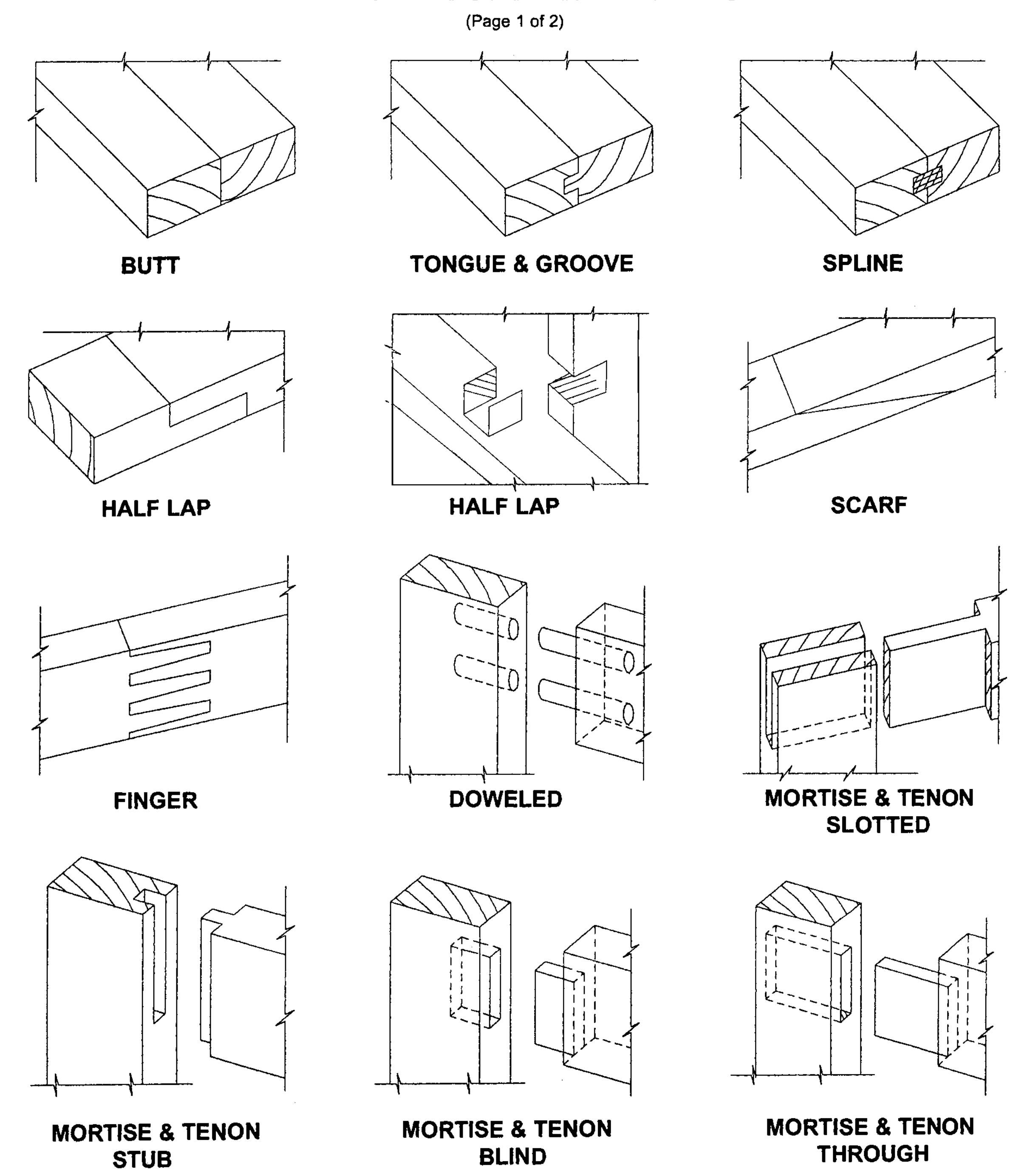
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6.3.2 Defining Exposed and Concealed Portions of a Cabinet



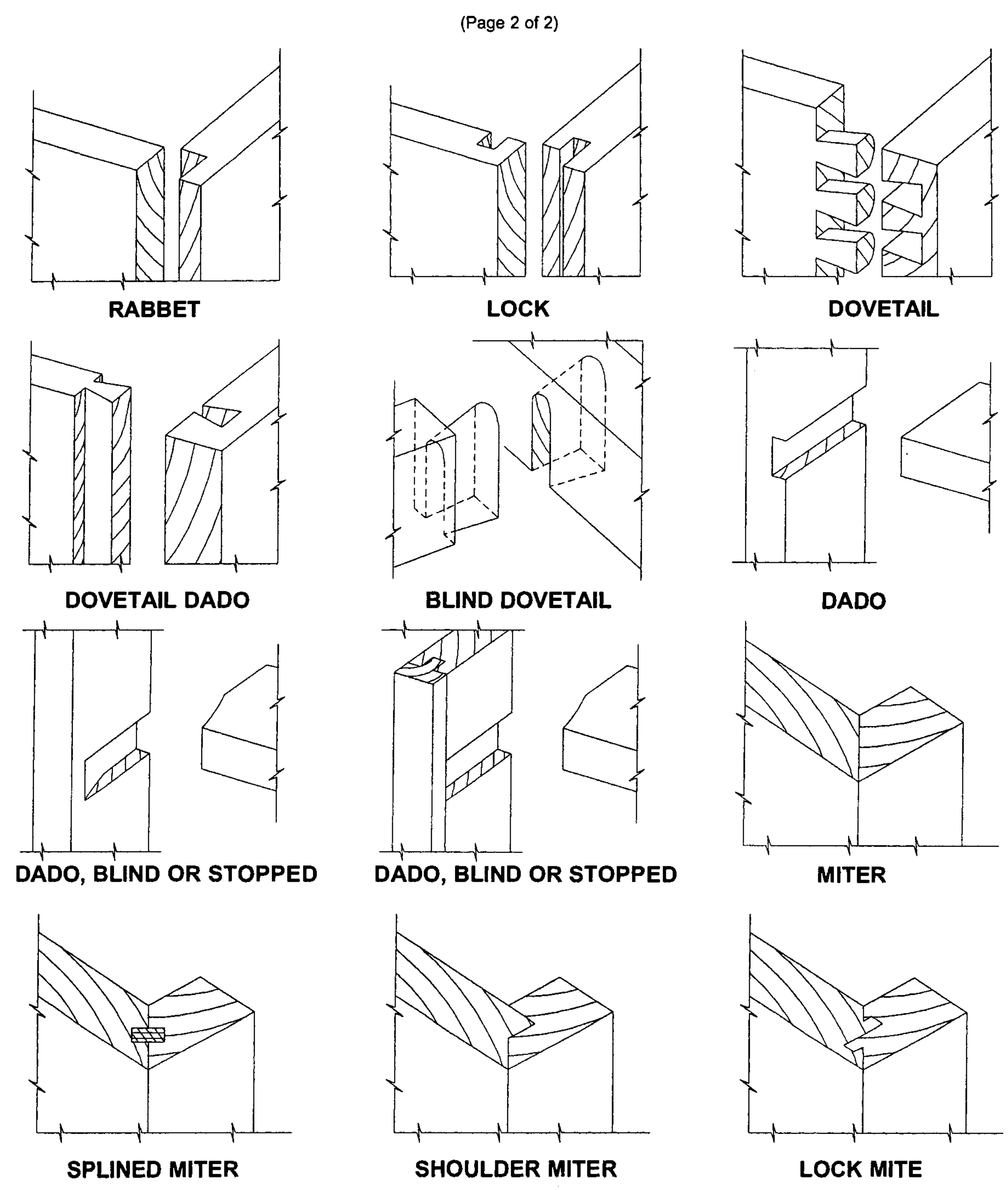
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6.3.3 Typical Joinery Details



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6.3.3 Typical Joinery Details (Continued)



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6.3.4 Casework Installation Requirements

GUIDELINES TO CASEWORK INSTALLATION REQUIREMENTS

ANCHORAGE FASTENERS used at:

WOOD or **METAL STUD WALL**S shall be a minimum #14 x 3", Truss Head Sheet Metal Screws.

MASONRY BLOCK shall be a minimum 1/4" x 31/4", Hilti, Kwik-Con II (ICBO #ER-5239) screws, or equal.

GENERAL NOTES:

Attachment requirements are based on a maximum 48" width cabinet unit for **TYPE I** construction or the undivided span for **TYPE II** construction.

Adjacent cabinet units shall be fastened together both front and back with a minimum of four (4) #8 x 1-1/4" flat, oval or pan head screws (binder head sex bolts are permitted), a maximum of 30" on center.

Toe bases at wall mounted base and tall cabinets are not required to be fastened to the floor; however, separate toe bases are required to be adequately secured to the cabinet bottom to prevent their moving.

Anchorage fasteners are intended for a minimum of 1-1/2" penetration of blocking and their length shall be increased as required to adjust for other finish and/or furring thicknesses.

Each wall hung or base cabinet unit or undivided span shall have a minimum of four (4) anchorage fasteners; two at the top and two at the bottom.

Each tall cabinet unit or undivided span shall have a minimum of six (6) anchorage fasteners; two at the top, two at the bottom, and two in the middle.

Vertically, anchorage fasteners shall be located within 2" of the outside top or bottom of the cabinet unit.

Horizontally, anchorage fasteners shall be located within 2" of the outside end of the cabinet.

The following schedule of fastener spacing is for a 48" wide wall hung, base or tall cabinet unit and/or undivided span, anchorage at narrower width units shall be proportional (island and/or peninsula cabinets are excluded, see special requirements):

MAXIMUM HORIZONTAL SPAN OF ANCHORAGE FASTENERS AT WALL HUNG, BASE AND TALL CABINETS

		Masonry Block			Wood Studs			Metal Studs		
WALL HUNG CABINETS		**Top**	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**
	48" x 30" x 18"	12"	16"	n/a	8"	16"	n/a	8"	16"	n/a
	48" x 48" x 18"	9-5/8"	12"	n/a	6"	8"	n/a	6"	12"	n/a
	48" x 30" x 13"	16"	16"	n/a	16"	16"	n/a	16"	16"	n/a
	48" x 48" x 13"	16"	16"	n/a	8"	16"	n/a	8"	16"	n/a
BASE CABINETS										
	48" x 42" x 24"	24"	24"	n/a	24"	24"	n/a	24"	24"	n/a
	48" x 42" x 36"	16"	16"	n/a	16"	16"	n/a	16"	16"	n/a
TALL CABINET										
	48" x 96" x 30"	16"	16"	16"	16"	16"	12"	16"	16"	9-5/8"

(continued)

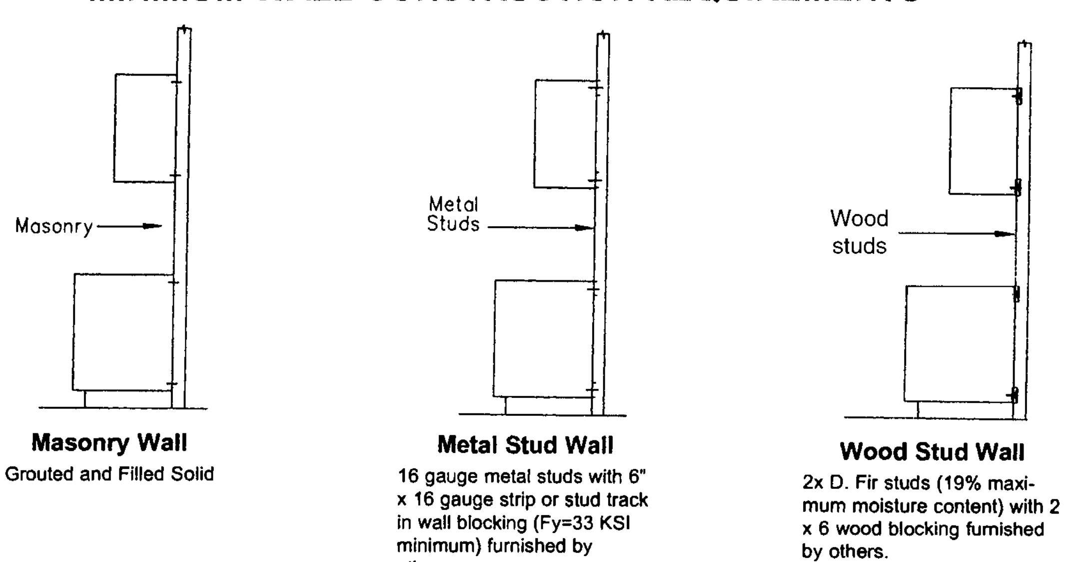
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6.3.4 Casework Installation Requirements (Continued)

GUIDELINES TO CASEWORK INSTALLATION REQUIREMENTS

The following represents the minimum wall construction specifications and installation requirements for installation of casework within the ***MANUAL OF MILLWORK***, regardless of **GRADE** specified. The **WOODWORK INSTITUTE** continues to seek approval of seismic compliant installation requirements for California: therefore, **THE FOLLOWING IS NOT REPRESENTED AS BEING SEISMIC COMPLIANT.** Further information about **SEISMIC INSTALLATION APPROVALS** may be found at **www.woodworkinstitute.com.**

MINIMUM WALL CONSTRUCTION REQUIREMENTS

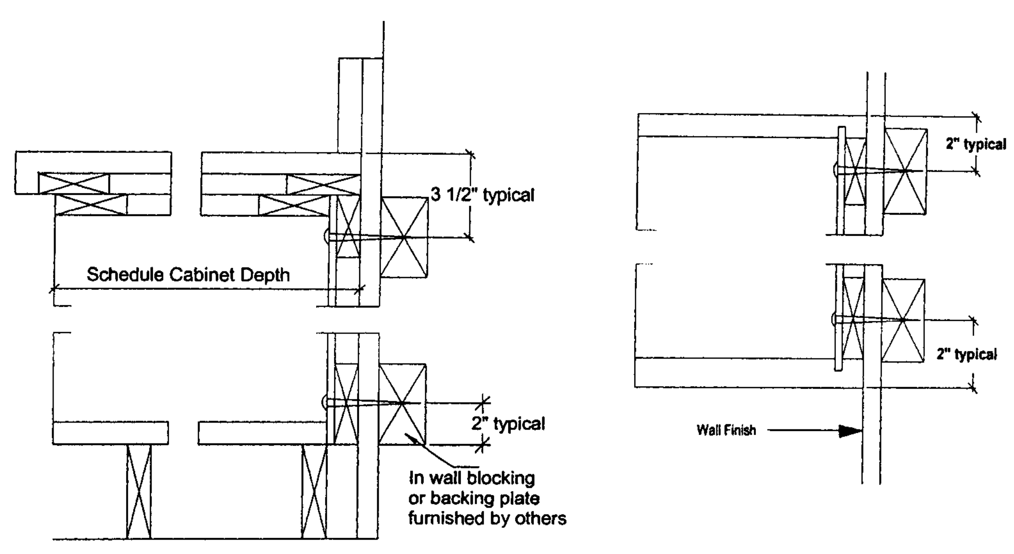


Masonry Wall
Grouted and Filled Solid

Metal Stud Wall
16 gauge metal studs with 6" x 16 gauge strip or stud track in wall blocking (Fy=33 KSI minimum) furnished by others.

Wood Stud Wall
2x D. Fir studs (19% maximum moisture content) with 2 x 6 wood blocking furnished by others.

TYPICAL VERTICAL ATTACHMENT LAYOUT:



Base Cabinet Section

Wall Cabinet Section

INSTALLATION REQUIREMENTS FOR TALL-PENINSULA/ISLAND CASEWORK (OVER 48" IN HEIGHT): SUCH AS LIBRARY SHELVING, ARE NOT PROVIDED BECAUSE OF THE NEED TO BE ENGINEERED ON AN INDIVIDUAL BASIS.

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6.3.5 Cabinet Hardware References

GUIDELINES TO ANSI/BHMA - A156.9-01 CABINET HARDWARE REFERENCES

The following tables and illustrations are from ANSI/BHMA's - A156.9-01: Cabinet Hardware Standards (one of a series of standards running from A156.1 through A156.24) and are reproduced here, with permission, as a guide for your reference.

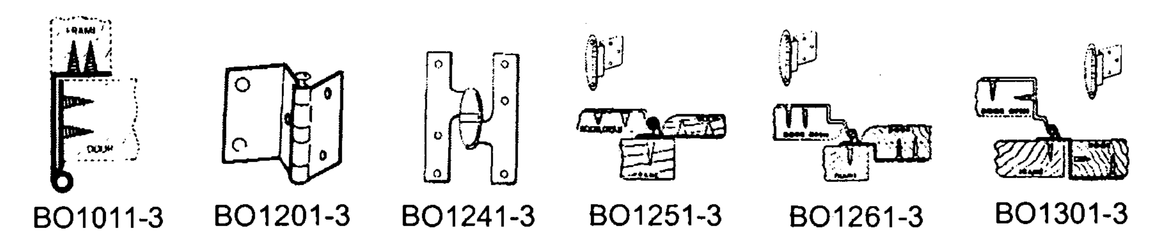
The following will help you to understand the numbering system. Using the first item listed below as an example, "B01011":

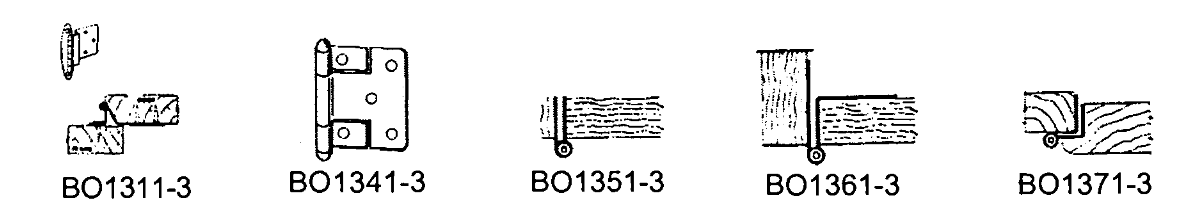
B	=	Product Class (as designated by BHMA)
0	=	Optional Material (predominant base material)
1	=	Hinge (product type)
01	=	Semi-concealed (function/description)
1	=	Grade 1 (performance level)

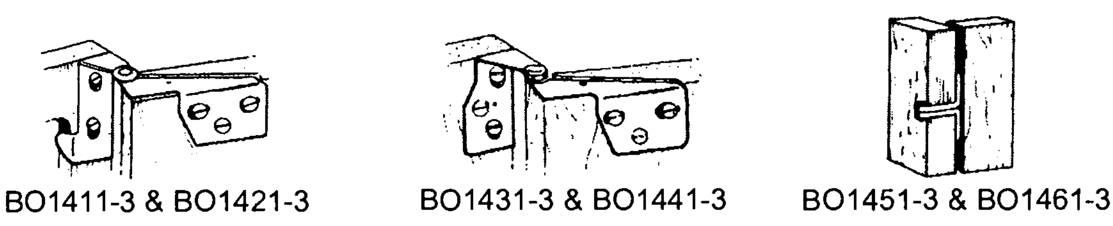
For further information, clarification or copies of the ANSI/BHMA Standards, you may contact BHMA at:

Builders Hardware Manufacturers Association
355 Lexington Avenue, Suite 1700, New York, NY 10017
www.buildershardware.com

CABINET HARDWARE REFERENCE BY ILLUSTRATION

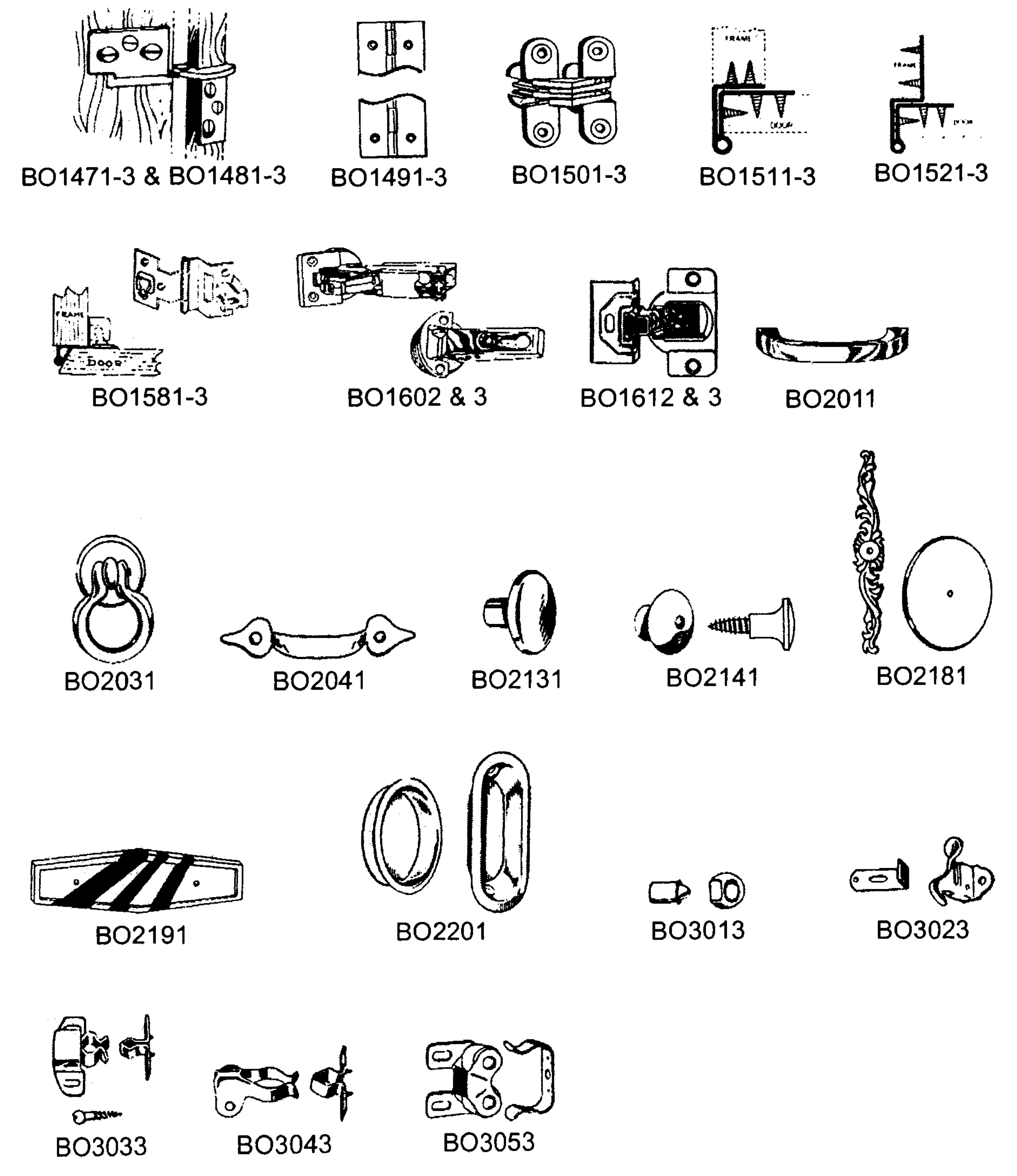






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6.3.5 Cabinet Hardware References (Continued)



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6.3.5 Cabinet Hardware References (Continued)

GUIDELINES TO CABINET HARDWARE REFERENCE BY DESCRIPTION

ANSI/ BHMA #	CABINET	DOOR	DESCRIPTION
BO1011-3	Face	Edge	Hinge, Semiconcealed, Overlay Doors, Locked, Knurled or Loose Pin, Rounded or Button Tip
BO1201-3	Edge	Edge/Back	Hinge, Semiconcealed, Flush Door, Loose or Fast Pin
BO1241-3	Face	Face	Hinge, Exposed, Flush Door, Olive Knuckle
BO1251-3	Face	Back	Hinge, Semiconcealed, Overlay Door
BO1261-3	Face	Back	Hinge, Semiconcealed, Inset Lipped Door
BO1301-1	Face	Back	Hinge, Semiconcealed, Flush Door
BO1311-3	Face	Back	Hinge, Semiconcealed, Reverse Bevel Door
BO1331-3	Edge	Back	Hinge, Semiconcealed, Inset Lipped Door
BO1341-3	Face	Back	Hinge, Semiconcealed, Overlay Door
BO1351-3	Edge	Edge	Hinge, Semiconcealed, Flush Door, Locked, Knurled or Loose Pin, Rounded or Button Tip
BO1361-3	Edge	Back	Hinge, Semiconcealed, Flush Door, Locked, Knurled or Loose Pin, Rounded or Button Tip
BO1371-3	Edge	Back	Hinge, Semiconcealed, Inset Lipped Door, Locked, Knurled or Loose Pin, Rounded or Button Tip
BO1411-3	Face	Back	Hinge, Pivot, Overlay Door, Top and Bottom Door Mount, Vertical Frame Mount
BO1421-3	Face	Back	Hinge, Same as above with bearing at joint
BO1431-3	Face	Back	Hinge, Pivot, Overlay Door, Top and Bottom Door Mount, Horizontal Frame Mount
BO1441-3	Face	Back	Hinge, Same as above with bearing at joint
BO1451-3	Edge	Back	Hinge, Pivot, Overlay Door, Mid-Door Edge Mount
BO1461-3	Edge	Back	Hinge, Same as above with bearing at joint
BO1471-3	Edge	Back	Hinge, Pivot, Lipped Door, Mid-Door Edge Mount
BO1481-3	Edge	Back	Hinge, Same as above with bearing at joint
BO1491-3	Face/Edge	Face/Edge/Back	Hinge, Continuous (Piano)
BO1501-3	Edge	Edge	Hinge, Concealed (Soss)
BO1511-3	Face	Edge/Back	Hinge, Semiconcealed, Overlay Door, Locked, Knurled or Loose Pin, Rounded or Button Tip
BO1521-3	Edge	Edge/Back	Hinge, Semiconcealed, Overlay Door, Locked, Knurled or Loose Pin, Rounded or Button Tip
BO1581 & 3	Face/Edge	Back	Hinge, Semiconcealed, Reverse Bevel Door, with Catch
BO1602 & 3	Edge	Back	Hinge, Concealed, European - Frameless
BO1612 & 3	Edge	Back	Hinge, Concealed, European - Face Frame

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6.3.5 Cabinet Hardware References (Continued)

GUIDELINES TO CABINET HARDWARE REFERENCE BY DESCRIPTION

ANSI/ BHMA #	CABINET	DOOR	DESCRIPTION
BO2011	n/a	Back	Pull, 3" Center Standard
BO2031	n/a	Back	Pull, Drop, Swing, or Fixed
BO2041	n/a	Face	Pull
BO2131	n/a	Back	Knob
BO2141	n/a	Face	Knob
BO2181	n/a	n/a	Backing Plate for Knobs
BO2191	n/a	n/a	Backing Plate for Pulls
BO2201	n/a	Face	Flush Pull, Mortised into Door Face
BO3013	Edge	Edge	Catch, Bullet or Ball Friction
BO3023	Edge	Back	Catch, Elbow
BO3033	Edge	Back	Catch, Friction
BO3043	Edge	Back	Catch, Friction
BO3053	Edge	Back	Catch, Roller Spring, Under Shelf Mount
BO3063	Edge	Back	Catch, Friction Spring
BO3071 & 2	Edge	Back	Catch, Roller
BO3091 & 2	Edge	Back	Catch, Roller
BO3112	Edge	Back	Catch, Roller
BO3131 & 2	Face	Back	Catch, Magnetic, Push in
BO3141 & 2	n/a	Back	Catch, Magnetic, Under Shelf Mount
BO3151-2	n/a	Back	Catch, Magnetic, Door Mount
BO3161-2	n/a	Back	Catch, Magnetic, Under Shelf Mount, Double Door
BO3171-2	Edge	Back	Catch, Magnetic, Heavy Duty
BO3243	Face	Face	Latch, Cupboard
BO3282	Edge		Pusher, for use with Secret/Touch Latches
BO3333	Edge	Back	Latch, Secret/Touch
BO3343	Edge	Back	Latch, Child Resistant
BO3352	Face	Face	Latch/Pull, Positive
BO3363	Edge	Back	Latch, Secret/Touch
BO4013			Shelf Rests, Cabinet, for bored holes
BO4063	Edge		Shelf Standard, Cabinet, Adjustable, Non-mortising
BO4073	Edge		Shelf Standard, Cabinet, Adjustable, Surface or Mortise Mounted
BO4081 & 3			Shelf Rest, Cabinet, Closed, for metal standard
BO4091 & 3			Shelf Rest, Cabinet, Open, for metal standard
BO4102 & 3			Shelf Standard, Slotted, Wall, Adjustable
BO4112 & 3			Shelf Bracket, for slotted standard
BO5011-3			Drawer Slide, Side Mount Bottom Capture
BO5081-3			Drawer Slide, Center Bottom Mount
BO5061-3			Drawer Slide, Center Top Mount
BO5051-3			Drawer Slide, Side Mount

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6.4.0 Wood Finishing Systems

TABLE 5 - 1
FINISHING SYSTEMS

	GENERIC TYPE	RECOMMENDED USAGE	CHARACTERISTICS
1.12.1	SYSTEM 1		
	a. NITROCELLULOSE LACQUER	General purpose/commodity: for all wood surfaces not requiring high performance properties and chemical resistance; interior use such as molding, furniture, cabinets, novelties, etc.	Nitrocellulose based; fast drying; easy to apply; low solids; sands easily; easy to re-coat/repair; yellows on aging; poor water/chemical resistance.
	b. ACRYLIC LACQUER	For all wood surfaces; interior use; best water white color.	Fast drying solvent based lacquer (acrylic-CAB); easy to apply; low solids; easy to recoat/repair; best clarity/resistance to yellowing.
	c. VARNISH - One Component	For all wood surfaces; interior use; spar varnishes for exterior use.	Alkyd type; good penetration into wood; slow dry; good build; yellows on aging.
	d. POLYURETHANE - One Component	For all wood surfaces; interior use; commonly used on floors.	Normally polyurethane modified alkyd or moisture cure urethane; hard tough surface; excellent wear and abrasion resistance; may yellow on aging.
1.12.2	SYSTEM 2 WATER REDUCIBLE ACRYLIC LACQUER	For all wood surfaces; interior use; where lowest VOC and flammability are required.	Water reducible latex quality; lowest VOC; does not contain flammable volatile solvents; lowest odor; best fire safety; higher solids/build than other lacquers; non-yellowing.
1.12.3	SYSTEM 3		
	a. CATALYZED LACQUER	For all wood surfaces requiring some chemical resistance; interior use - office furniture, cabinetry, doors, etc.	Fast drying catalyzed system - pot life; applies and handles like a lacquer; improved hardness; toughness/chemical resistance compared to lacquer; may yellow on aging; touch up/repairs more difficult.
	b. CATALYZED VINYL LACQUER	Better acid resistance; excellent chemical resistance for laboratory furniture; interior use.	Fast drying catalyzed system - pot life; good tough wearing surface; may yellow; repairs may be difficult; best chemical resistance.
1.12.4	SYSTEM 4 CONVERSION VARNISH (Clear and Opaque)	For all wood surfaces; excellent overall quality; widely used for cabinetry and furniture; available as clear or opaque pigmented coatings; for interior use.	Two-package acid catalyzed system - pot life; hard, tough film with very good resistance properties; high solids\build compared to lacquers; may yellow; hard to repair. Includes water reducible conversion varnish technology.
1.12.5	SYSTEM 5 CATALYZED POLYURETHANE	For all wood surfaces; clear - for interior use; pigmented - for interior/exterior use and "wet look".	Two-package - limited pot life; very hard, tough surface; excellent wear and chemical resistance; may yellow on aging; difficult to repair; many quality/performance levels available.
1.12.6	SYSTEM 6 PENETRATING OIL	For all wood surfaces; performs well on oak, teak, walnut, etc.; interior use; oil finish/close to the wood look.	Easy to apply; easy touch-up and repair; average to low resistance properties.
1.12.7	SYSTEM 7		
	a. SYNTHETIC ENAMEL	For all wood surfaces; interior/exterior use; many opaque colors.	Easy to apply; can be recoated and repaired; good coverage/build.
	b. OPAQUE PIGMENTED LACQUER	Interior use on wood; also used for industrial finishing of metal.	Pigmented alkyd nitrocellulose; fast dry; easy to apply; easy to recoat/repair; normally a primer/topcoat system; available in wide range of colors/sheens.
1.12.8	SYSTEM 8 UV CURABLE COATING	UV curable coatings can be divided into two categories for wood finishing flatline and three dimensional. Used typically in wood paneling and doors.	UV coatings are normally lower in VOC. They can improve processing time, reduce labor costs, and improve product consistency. Major technologies are in acrylic and polyester types.
1.12.9	SYSTEM 9 FIRE RETARDANT COATING (Intumescent)	For surfaces of wood products requiring flame spread protection. Interior use only. UL Rated - UL - 723; NFPA-255; ASTM E-84; tested for flame spread; fuel contributed and smoke developed.	Leaching will result if exposed directly to humidity or direct water. Can be coated with compatible overcoat system or waterproofing materials. Available for transparent and opaque finishes.
1.12.10	SYSTEM 10 POWDER COATING	For engineered wood products requiring a protective coating; interior use - office furniture, cabinetry, residential furniture.	Powder Coatings contain no VOCs, HAPs, heavy metals, or solvents. They increase productivity by reducing process time and labor costs while producing seamless edges that resist moisture and heat.

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6.4.0 Wood Finishing Systems (Continued)

1.13 RATED COMPARISON OF FINISHING SYSTEMS (see TABLE 5-1)

TABLE 5 - 2

	System:	1				2	3		4	5	6	7		8	9	10
1.13.1	Characteristics	(a)	(b)	(c)	(d)		(a)	(b)				(a)	(b)			
1.13.2	Household Chemicals	3	3	3	3	3	4	5	4-5	5	2	3	3	4	3	4
1.13.3	Abrasion Resistance & Toughness	2	2	3	3	3	4	4	5	5	1	3	3	4-5	3-4	4
1.13.4	Moisture Resistance	2-3	2-3	3	3	3	4	5	4	5	2	3-4	3	4-5	1	5
1.13.5	Build /Solids	2	2	3	3	4	3	3	4	3-4	1	4	3	5	2	5
1.13.6	Dry Time	5	5	2	2	3	5	5	4	2-3	2	2	4	5	2	5
1.13.7	Yellowing	1	5	3	2	4-5	2-3	3	4	3-4	2	3	3	4-5	3	3-4
1.13.8	Catalyzed	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	Yes /No	No	No
1.13.9	Repairability	5	5	3	3	3	3	2	2	1	5	2	3-4	2	4	2-3
	5 = Excellent; 4 = Very Good; 3 = Good; 2 = Fair; 1 = Poor															

1.14 APPLICATION CHARACTERISTICS OF FINISHING SYSTEMS (see TABLE 5-1)

TABLE 5 - 3

	SYSTEM	SOLVENT TYPE	RESIN TYPE	COMPATIBLE SOLVENTS	APPLICATION METHODS
1.14.1	1a - Nitrocellulose Lacquer	Solvent	Nitrocellulose	Lacquer Thinner, Ketones, Acetates	Conventional, Airless, AAA, HVLP
1.14.2	1b - Acrylic Lacquer	Solvent	CAB-Acrylic	Lacquer Thinner, Ketones, Acetates	Conventional, Airless, AAA, HVLP
1.14.3	1c - Varnish	Solvent / Water	Alkyd	Mineral Spirits, VM&P Naphtha	Brush, Conventional, Airless, HVLP
1.14.4	1d - Polyurethane	Solvent / Water	Polyurethane	Mineral Spirits, VM&P Naphtha	Brush, Conventional, HVLP
1.14.5	2 - Water Reducible Acrylic Lacquer	Water	Acrylic Latex	Water	Brush, Conventional, Airless, AAA, HVLP
1.14.6	3a - Catalyzed Lacquer	Water	Nitrocellulose / Alkyd Amino	Lacquer Thinner, Ketones, Acetates	Conventional, Airless, AAA, HVLP, Electrostatic
1.14.7	3b - Catalyzed Vinyl Lacquer	Solvent	Vinyl Alkyd Amino	Lacquer Thinner, Ketones	Conventional, Airless, AAA, HVLP
1.14.8	4 - Conversion Varnish	Solvent	Alkyd Amino	Xylol, Totuol, Hi-Flash Naphtha, Ketones	Conventional, Airless, AAA, HVLP
1.14.9	5 - Catalyzed Polyurethane	Solvent	Polyurethane	Ketones	Conventional, Airless, Electrostatic, AAA, HVLP
1.14.10	6 - Penetrating Oil	Solvent	Alkyd	VM&P Naphtha, Aromatics, Aliphatics	Spray, Dip, Brush
1.14.11	7a - Synthetic Enamel	Solvent	Alkyd / Acrylic	VM&P Naphtha, Mineral Spirits	Brush, Dip, Conventional, HVLP , Airless, AAA
1.14.12	7b - Opaque Pigmented Lacquer	Solvent	Nitrocellulose / CAB-Acrylic	Ketones, Acetates	Conventional, Airless, AAA, Dip, HVLP ,
1.14.13	8 - UV Curable Coating	Solvent / Water	Epoxy / Acrylic / Polyurethane / Polyester	Consult with Coating Supplier	Spray, Rollcoat, Curtain Coat
1.14.14	9 - Fire Retardant Coating	Solvent / Water	Acrylic Latex / Alkyd	Water / Mineral Spirits	Brush, Roll, Conventional, Airless, AAA, HVLP
1.14.15	10 - Powder Coat	None	Epoxy / Polyester / Acrylic / Hybrid	n/a	Electrostatic Spray

6.5.0 High-Pressure Plastic Laminates (HPLs)—Grades and Functions

GRADE DEFINITIONS

Grade 10 General Purpose Grade (HGS, Nominal Thickness .048" (1.2mm))
The most widely specified grade; recommended for horizontal and vertical interior applications.

Grade 12 Horizontal Postforming Grade (HGP, Nominal Thickness .039" (1.0mm))
Postformable to permit bending on suitable commercial postforming equipment. Use whenever forming is desired for decorative or functional purposes in interior applications. Optimum postforming temperature is 325°F (163°C). Note: When used with a polished finish, Grade 12 is recommended only for light duty horizontal applications.

Grade 20 Vertical Postforming Grade (VGP, Nominal Thickness .028" (0.7mm))
Outside and inside radii to 3/8" (9.5mm). A forming grade designed for vertical or light duty horizontal interior applications requiring radiused edges. Thinner than Grade 12; excellent for postformed radii. Installed panel width not to exceed 24" (609.6mm) maximum.

Grade 32 Fire-Rated Vertical Grade (VGF, Nominal Thickness .032" (0.8mm))
Intended for use in vertical and horizontal interior applications which require low flame spread ratings to conform to building codes. Classified by Underwriter's Laboratories, Inc. and meets most military and marine specifications. Slightly thinner than Grade 50. *Available on selected Fire-Rated Laminate items.*

Grade 50 Fire-Rated General Purpose Grade (HGF, Nominal Thickness .048" (1.2mm))
Intended for use in vertical and horizontal interior applications which require low flame spread ratings to conform to building codes. Classified by Underwriter's Laboratories, Inc. and meets most military and marine specifications. *Available on selected Fire-Rated Laminate items.*

Grade 51 General Purpose Grade (HGS, Nominal Thickness .050" (1.2mm))
Dimensional laminate for horizontal and vertical interior applications. Similar in properties to Grade 10. Available only for Corrugation Finish.

Grade 52 General Purpose Postforming Grade (HGP, Nominal Thickness .039" (1.0mm))
Postformable to permit bending on suitable commercial postforming equipment. Used whenever forming is desired for decorative or functional purposes in interior applications. Similar in properties to Grade 12. *Available only for Corrugation Finish*

Grade 53 Vertical Postforming Grade (VGP, Nominal Thickness .028" (1.0mm))
Postformable to permit bending on suitable commercial postforming equipment. Used whenever forming is desired for decorative or functional purposes in interior applications. Similar in properties to Grade 20. *Available only for Corrugation Finish*

Grade 54 Vertical Dimensional Grade (VGD, Nominal Thickness .047" (1.2mm))
Dimensional laminate for vertical interior applications. *Available within the Punched and Quilted Collections.*

Grade 87 Fire Rated Backing Sheet Grade (BLF, Nominal Thickness .028" (0.7mm))
Non-decorative surface; light duty interior use, fire-rated backing sheet for balancing and moisture control of laminate panels. *Available on selected Fire-Rated Laminate Backing Sheet items.*

Grade 89 Fire Rated Backing Sheet Grade (BCF, Nominal Thickness .048" (1.2mm))
Non-decorative surface; general purpose interior use fire-rated backing sheet for balancing and moisture control of laminate panels. *Available on selected Fire-Rated Laminate Backing Sheet items.*

Grade 91 Backing Sheet Grade (BKL, Nominal Thickness .020" (0.7mm))
Non-decorative surface; light duty interior use backing sheet for balancing and moisture control of laminate panels. *Available on selected Backing Sheet items.*

Grade 92 Backing Sheet Grade (BKH, Nominal Thickness .048" (1.2mm))
Non-decorative surface; general purpose interior use backing sheet for balancing and moisture control of laminate panels. *Available on selected Backing Sheet items.*

Honed* (-77)
A low sheen satin finish with subtle surface clefts and crevices that mimic softly brushed stone. Recommended for horizontal and vertical interior applications. *Available on specific colors within the Honed Collection.*

Polished (-90)
A high-gloss finish ideal for applications that require maximum smoothness and reflectance. Recommended for light-duty horizontal or vertical interior applications. This finish is not recommended for heavy-duty horizontal applications such as countertops. *Available on all Solid Colors, Patterns, and Woodgrains.*

Chemtop2 (CT)
This finish resists chemicals, stains, impact, and heat. Recommended for horizontal and vertical interior applications. *Available on specific colors within the Chemtop2 - Special Laminate Product.*

Velour (FV)
A non-directional, satin finish that is smooth to the touch. Recommended for horizontal and vertical interior applications. *Available on specific colors within the ColorCore2 - Special Laminate Product.*

By permission, Formica Corporation, Cincinnati, Ohio.

6.5.0 High-Pressure Plastic Laminates (HPLs)—Grades and Functions (Continued)

Luxe (LX)
Contrasting matte wood tick structure in a polished background gives a realistic finish depth and adds elegance to wood surfaces. Recommended for horizontal and vertical interior applications. *Available on selected Woodgrains.*

MicroDot (MC)
A low-sheen finish with subtle, with concave circles arranged in a tight grid formation. Recommended for horizontal and vertical interior applications. *Available on specific colors within the MicroDot Collection and ColorCore2 - Special Laminate Product.*

Naturelle (NT)
Subtle straight grain ticking creates a realistic natural wood look and low sheen finish. Recommended for light-duty horizontal or vertical interior application. This finish is not recommended for heavy-duty horizontal applications such as countertops. *Available on selected Woodgrains.*

Grade FG frpSelect General Purpose Vertical Grade (HGV, Nominal Thickness .090" (2.3mm))
Recommended for vertical interior applications. *Available on frpSelect items only.*

Grade P7 Compact Structural Laminate Grade (Nominal Thickness .250" (6mm))
Two-sided decorative panel with blackcore; recommended for horizontal and vertical interior applications. *Available on all Solid Colors, Patterns and Woodgrains.*

Grade P8 Compact Structural Laminate Grade (Nominal Thickness .625" (15.9mm))
Two-sided decorative panel with blackcore; recommended for horizontal and vertical interior applications. *Available on all Solid Colors, Patterns and Woodgrains.*

Grade R3 Compact Structural Laminate Grade (Nominal Thickness 1.00" (25.4mm))
Two-sided decorative panel with blackcore; recommended for horizontal and vertical interior applications. *Available on all Solid Colors, Patterns and Woodgrains.*

Grade S6 Compact Structural Laminate Grade (Nominal Thickness .500" (12.7mm))
Two-sided decorative panel with blackcore; recommended for horizontal and vertical interior applications. *Available on all Solid Colors, Patterns and Woodgrains.*

Grade S7 Compact Structural Laminate Grade (Nominal Thickness .750" (19mm))
Two-sided decorative panel with blackcore; recommended for horizontal and vertical interior applications. *Available on all Solid Colors, Patterns and Woodgrains.*

Grade S8 Compact Structural Laminate Grade (Nominal Thickness .375" (10mm))
Two-sided decorative panel with blackcore; recommended for horizontal and vertical interior applications. *Available on all Solid Colors, Patterns and Woodgrains.*

By permission, Formica Corporation, Cincinnati, Ohio.

6.5.1 Tips to Avoid Panel Warping

Avoiding Warpage of Laminate-Clad Panels

CAUSES OF PANEL WARPAGE

Laminate-clad panels are susceptible to warpage if they are not physically restrained or balanced. Balanced panel construction equalizes the forces acting on both sides of the core material. If for any reason these forces become unbalanced, warpage can result.

Warpage of wood product panel assemblies (e.g., laminate-clad particleboard or MDF) is attributed to the differences in dimensional movement between the face and back laminates and the core or substrate material. This movement and its subsequent stresses are caused by the expansion or contraction of paper fibers in the laminate skins and wood fibers in wood composite cores as they respond to relative humidity changes. The stress and dimensional movement generated within a laminate skin are transmitted to the core through its glue line. The forces involved are tremendous and, if they are not properly considered in the panel design, warpage can result.

The use of laminates and substrates that have different strengths and/or dimensional movement potentials is not the only cause of warpage. Exposing one side of a panel assembly to different humidity conditions than the other side can also cause warpage. For example, a "balanced" panel will warp if one side is exposed to air conditioning and the other is against a damp, below-grade wall (e.g., basement wall without a proper moisture barrier).

TIPS FOR AVOIDING PANEL WARPAGE

1. All panel components should be acclimated to the same environment prior to assembly. This will ensure that one component will not be contracting while the other is expanding due to subsequent relative humidity changes. In addition, under extreme conditions, materials that have not been properly acclimated to the same condition prior to fabrication, can buckle or delaminate, as well as warp. Proper preconditioning of materials can also help to minimize shrink-back or laminate growth problems on machined edges.

2. For critical applications requiring a well-balanced assembly (doors, etc.), the same laminate or skin should be applied on both sides. Less critical applications may only require a cabinet liner or phenolic backer. Small components and mechanically restrained panels (countertops, etc.), on the other hand, may not need balancing sheets.

3. Thick panels warp less than thin panels due to increased rigidity and the geometry of the forces involved. For critical applications, the thickest core material permissible should be selected to help minimize warpage.

4. Laminates expand and contract twice as much in their cross-grain direction as they do in their grain (parallel with the sanding lines) direction. Always align the sanding lines of the front and back laminates in the same direction and, wherever possible, align the grain direction of the laminate with the longest panel dimension. It is also advisable to align the grain and cross-grain directions of the laminates with that of the substrate.

   Note: **When multiple panels are viewed together, keep all laminate components aligned in the same direction to minimize visual changes in color or gloss due to the directionality of the underlying surface paper and laminate finish.**

By permission, Formica Corporation, Cincinnati, Ohio.

6.5.1 Tips to Avoid Panel Warping (Continued)

5. Use the same adhesive and application techniques (application rate, method of application, drying techniques, etc.) for bonding the front and back laminates. This is especially important when using water-based adhesives such as PVAc (white glue), ureas or water-based contacts which introduce additional moisture into the panel assembly. In addition, if panels are being hot pressed, the top and bottom platen temperatures may require temperature adjustments to produce flat panels. Temperatures used to effect glue line cure can cause shrinkage of the glue and surfacing materials. Generally, the side having the thicker skin will require a slightly higher platen temperature than the side having a thinner skin (cabinet liner, phenolic backer, etc.), due to heat transfer rates. Bottom platen temperature may also require reduction to compensate for the additional contact time involved while the press is being closed and opened.

6. Moisture barriers such as paint, varnish, vinyl film, and other coverings including impregnated fiber backers, will not balance a panel having a laminate on the other side. Coatings or materials of this type do not exhibit the same strength or dimensional change characteristics as a laminate. Remember, the strength and expansion/contraction rates of the face and back skins must be matched for proper balancing.

7. Installed laminate-clad panels will expand and contract with humidity changes. Provide sufficient spacing between panels to allow for this. Panels or countertops that are locked between two walls or other such restraints should have a sufficient gap allowed to accommodate dimensional movement. Wider panels and higher humidity swings require more spacing. A general rule of thumb is to allow 1/8" (3.18mm) minimum between panels having widths of 48" (121.9cm).

SUMMARY

- Acclimate or precondition materials.
- Use same laminate on both sides unless panel is small or mechanically restrained.
- Thick core resists warpage better than thin core.
- Align sanding marks on both sides.
- Use the same adhesive and application techniques on both sides.
- Paint, varnish, vinyl film and fiber backers will not balance high pressure laminates.
- Spacing is required between panels to allow for movement.

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6.5.2 HPL Stress Crack Avoidance

CAUSES OF STRESS CRACKING

Stress cracking of high pressure laminate is caused by the concentration or buildup of stresses in a particular area of a laminated assembly. When this stress becomes greater than that which the laminate can withstand, a stress crack will occur. If such stresses are allowed to concentrate around a cutout or other such fabrication detail, one or more cracks can characteristically radiate from the sharper corners of the cutout, where, for mechanical reasons, the laminate is weakest.

These stresses can be caused by external mechanical forces, but are generally caused by the normal dimensional movements of the laminated assembly as it reacts to the surrounding environment. As with all wood-based products, high pressure laminates and their substrates react to humidity changes. Under moist conditions, laminated assemblies gain moisture and expand dimensionally. When this same assembly is subjected to dry conditions, however, this moisture is lost and shrinkage results. If the laminate shrinks more than the substrate, stress cracking of the laminate surface can occur in certain areas.

TECHNIQUES FOR CONTROLLING STRESS CRACKING

The occurrence of stress cracking can be greatly minimized by using fabrication techniques and practices which recognize and moderate the dimensional movement and associated stresses that can develop within a laminated assembly.

These techniques and practices consist of:

- Preconditioning
- Proper substrate selection
- Obtaining a good adhesive bond
- Proper inside corner fabrication
- Proper seam placement
- Good installation practices

PRECONDITIONING

Prior to the fabrication, allow the laminate and substrate to acclimate for at least 48 hours to the same ambient conditions. Optimum conditions are approximately 75°F (24°C) and a relative humidity of 45% to 55%. Provision should be made for the circulation of air around the components.

SUBSTRATE SELECTION

Formica® brand laminate and ColorCore® surfacing material should be bonded to either Medium Density Fiberboard (MDF) or a 45# density industrial grade particleboard (CS 236-66: Type 1, Grade B, Class 2). The dimensional change properties of these substrates, being similar to that of high pressure laminate, greatly reduce the potential for stress cracking when the assembly is subjected to low humidity conditions.

Plywood substrates should be avoided, whenever possible, for use with Formica brand laminate, and should never be used as a substrate for ColorCore surfacing material. Because of its cross-ply construction, plywood expands and shrinks less than either of these laminate grades. This results in greater stress built up within the laminate, and thereby increases the chance of stress cracking.

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6.5.2 HPL Stress Crack Avoidance (Continued)

ADHESIVE BOND

The quality and nature of the bond between the laminate and the substrate is also an important factor to consider when trying to minimize stress cracking. Basically, the stronger and more rigid the bond, the less are the chances for stress cracking. Contact adhesives, by their nature, are elastomeric and, therefore, transfer less of the stress to the substrate. Assemblies made with contact adhesives, therefore, are less crack resistant than those fabricated with rigid or semi-rigid adhesives. If contact adhesives are used, they should be properly applied and fused to obtain the strongest possible bond.

Rigid and semi-rigid adhesives such as resorcinol, ureas and PVAc (white glue) transfer stresses directly to the substrate. Assemblies fabricated with these adhesives are more crack resistant.

The stress crack performance of assemblies using contact adhesive can be greatly improved if a PVAc (white glue) is used at all inside corners. *Note:* If the assembly is to be water resistant, a catalyzed PVAc glue should be used.

1. The cutout area of the laminate and substrate assembly is masked prior to applying the contact adhesive.

2. Once the contact adhesive has been applied and dried, the masking is removed and a PVAc glue is applied.

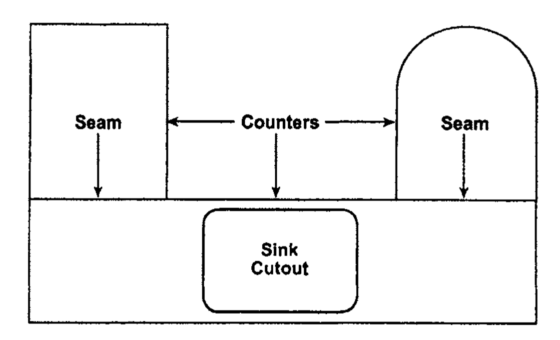
3. The laminate and substrate are then joined and nip rolled together to fuse the contact adhesive. The masked-off area is then clamped until the adhesive sets. This usually takes about one hour.

INSIDE CORNER FABRICATION

The inside corners of all cutouts must be radiused as large as possible (1/8" (3.18mm) minimum) to minimize stress cracking. A radiused corner created by a 1/4" (6.36mm) diameter router bit is normally used. All edges and inside corners should be filed smooth and free of any chips or nicks.

SEAM PLACEMENT

Another effective means of minimizing the chances of stress cracking is to plan the placement of seams to reduce the number of inside corners. An example of proper seam position is shown in the following illustration.



By permission, Formica Corporation, Cincinnati, Ohio.

6.5.2 HPL Stress Crack Avoidance (Continued)

INSTALLATION

Install the laminated assembly with sufficient clearance at pipes, electrical boxes, panel edges, etc., to allow for normal dimensional movement. Sinks, louvers, drop-in ranges, etc., should fit easily into openings without binding. Do not install a panel or laminated assembly by force fitting. Panels should be installed in a flat plane by shimming, as necessary, to avoid mechanical stresses caused by bending or twisting.

SUMMARY

1. Precondition laminate and substrate for a minimum of 48 hours prior to fabrication. Optimum conditions are approximately 75°F (24°C) and 45% to 55% relative humidity

2. Select the proper substrate: MDF or 45# density particleboard. Plywood should not be used with ColorCore surfacing material.

3. Obtain a good bond. Assemblies bonded with rigid or semi-rigid adhesives are more crack resistant than those assembled with contact adhesives.

4. Radius inside corners as large as possible, 1/8" (3.18mm) minimum.

5. Plan the placement of seams to minimize inside corners.

6. Provide sufficient clearance at sinks, electrical boxes, range cutouts, etc., to allow for dimensional movement. Do not force fit. Do not induce mechanical stresses.

By permission, Formica Corporation, Cincinnati, Ohio.

6.5.3 Easy Installation for HPL Countertops

Easy Installation Instructions for Countertops

Enjoy the beauty, durability and convenience of Formica® brand laminate countertops that you can install yourself. New countertops are economical when you can do the work yourself to update a bathroom, kitchen, hobby or work area.

Getting Started

Assemble the right tools and materials before you start. Be sure to read instructions, work in a well-ventilated room and wear safety glasses when using any power tool.

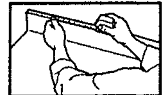
Required Tools and Materials:

Before starting, gather materials essential for installing a typical L-shaped kitchen countertop with a cutout for a sink or rangetop installation. Work with your Lowe's sales associate to:

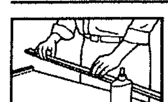
1. Order countertop sections in standard lengths. Ask Lowe's to miter cut and machine the fastening-bolt T-slots (underside of the joint) for you.
2. Have available, or purchase the following:
   - Fastening bolts (for drawing miter joints tight)
   - Tube of sealant such as Formica® brand caulk (for caulking joints)
   - End splash and/or end caps (kits, as required)
   - Non-flammable contact adhesive (for fastening end caps unless the kit has pre-applied adhesive for "iron-on" method)
   - White glue (for fastening "build-up" blocks)

Required Tools:

- Saber saw
- Drill and drill bit
- Block plane
- Belt sander
- C-clamps
- Safety glasses
- Rubber mallet
- Level
- Square
- Hammer
- Handsaw
- Scriber-compass
- Adjustable wrench
- Screwdriver
- Sandpaper
- Caulk gun



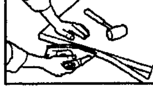
Step 1 Fit and Cut
- Measure and check fit for correct length including allowance for overhang
- Before sawing, cover the Formica® brand laminate surface with a strip of masking tape and draw a pencil line on the tape for a cutting guide
- Cut using a fine-tooth handsaw (10-12 point), cutting into the laminate surface to avoid chipping
- Sand or file the cut for a smooth surface



Step 2 Build Up
- Place countertop upside down on a flat surface
- Match front buildup with strips of wood
- Glue the strips around the perimeter of countertop



Step 3 End Caps (check instructions included in the end cap kit)
- Set household iron at medium heat
- Iron cap onto the end of the countertop using a back-and-forth motion
- Allow to set and cool for 1 minute
- Tap the cap carefully with a rubber mallet
- Trim with a fine file, applying pressure only on the up strokes

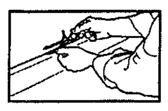


Step 4 Cutouts
- Position the sink or rangetop rim on the backside of the countertop where the appliance is to be located
- Mark all the way around the edge of the rim
- Use a saber saw to cut a hole 1/4" to 3/4" smaller than the line, making sure that the corners have clean, chip-free radii

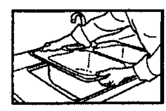
Note: Follow manufacturers' directions for installing appliances.



Step 5 Joining Miters (L- or U-shaped countertops only)
- Apply a bead of sealant such as Formica® brand caulk to each precut mitered edge
- Tighten fasteners just enough to hold them in place
- Align front edges and tighten fasteners
- Tap surfaces to align (use woodblocks to avoid damaging the surface)
- Tighten fasteners securely



Step 6 Scribing
- Match countertop to wall surface by scribing (top has a scribe edge on the backsplash for this purpose
- Place countertop on the cabinet
- Using a scriber-compass, mark the edge of the countertop
- Belt-sand or block-plane to the line to contour the countertop to the wall
- Put top in place, check for level and stability
- Secure top to cabinets with wood screws



Step 7 Installing Sinks
- Install sink faucet, 3/8" tubing and basket drain before dropping sink into place
- Seal to avoid water damage to base material

Step 8 Finishing
- Remove excess sealant from sink area or end splash
- See *Doityourself Use and Care Guidelines* for further information

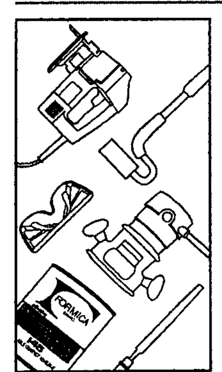
By permission, Formica Corporation, Cincinnati, Ohio.

6.5.4 Easy Instructions for HPL Surfaces

Installation Instructions for Easy Laminated Surfaces

Give your kitchen or bath a fresh new look with Formica® brand laminate. With careful planning you can do-it-yourself without the wait or additional labor costs. You can get results that will make you glad you did it yourself.

Formica® brand laminate is easy to install, easy to clean and care for. That means your new countertops will give you years of carefree pleasure and enjoyment. Choose from a large variety of colors and patterns to get the look you want.



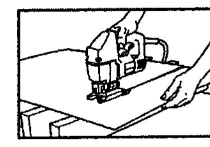
Step 1 Getting Started

Having the right tools on hand will make the job go quickly and easily. Keep in mind that you should work in a well-ventilated room and wear safety glasses when using any power tool. Before beginning, read adhesive precautions and directions.

If you are building new countertops, particleboard is recommended for the core material. On countertops with square edges, Formica® brand laminate can be installed over the existing laminate – provided it has been cleaned, degreased and lightly sanded.

Required tools and materials:

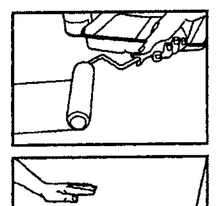
- Saber saw with metal cutting or fine-tooth cutting blades
- Safety glasses
- J-roller
- Router and laminate trimming bit
- Fine tooth mill file
- Brush, roller and trowel (see adhesive can for recommendations)
- Formica® brand contact adhesive
- Dowel rods



Step 2 Make the Cut

Before cutting your laminate surface, check corners with a carpenter's square so you won't have problems later. Cut laminate with a saber saw, using a fine tooth blade or a table saw with fine carbide tipped blade. If needed, also cut edge strips for Formica® brand laminate, or wood moldings can be used as edging.

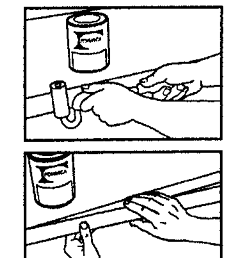
Warning: Measure surface to be covered carefully. Cut core material to size. Be sure to cut laminate surface 3/8" to 1/2" larger than the surface to be covered.



Step 3 Put it Together

Surfaces

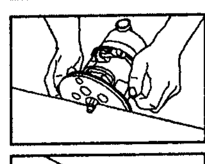
- Apply adhesive to back of laminate with a roller. Follow instructions on adhesive can
- Apply adhesive to core (dirt-free particleboard or old surface)
- Allow adhesive to dry completely
- Position dowel rods 6" apart on core
- Position laminate on top of dowel rods
- Align surfaces and slide rods out
- Immediately apply pressure with a J-roller

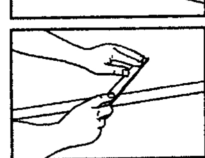


Edges

- Apply adhesive to laminate edge strip, following instructions on adhesive can
- Apply 2 coats of adhesive to core edge of countertop
- Bond edge strip to core using pressure

Note: Some adhesives contain flammable solvents. Follow instructions on adhesive can.





Step 4 Finishing Touches

- Trim excess with router and laminate trimming bit
- File edge flush, removing sharp edges

Note: To prevent moisture damage to the core materials seal all seams, including a backsplash, with caulk.

By permission, Formica Corporation, Cincinnati, Ohio.

6.6.0 Painting—An Introduction to Paint Technology

Introduction to paint technology



Most paints can be classified according to their vehicles or binders which are described below in alphabetical order:

Alkyd

Alkyds are coatings produced by reacting a drying oil acid with an alcohol. Drying of the surface occurs by the evaporation of a solvent; curing of the resin occurs by oxidation. The more oil there is in the formula, the longer it takes to dry, the better the wetting properties, and the better the elasticity. Alkyds can be used as interior or exterior trim paints, machinery enamels, or durable wall finishes. To avoid saponification, alkyd coatings should not be used directly on masonry, galvanized metal or other alkaline surfaces except over an alkali resisting primer or sealer.

Epoxy—Catalyzed

Catalyzed epoxies are coatings produced by combining an epoxy resin with a curing agent. Solvent evaporation causes the surface to dry while a chemical cross-linking process, called copolymerization, is the curing mechanism. The mixture has a limited time of workability, referred to as "pot life", which may vary from a few minutes to several hours depending on the formulation. When properly cured, catalyzed epoxy coatings have excellent solvent and chemical resistance. They are excellent coatings for walls, producing a surface that is highly resistant to abrasion, chemicals, and cleaning. Many epoxy coatings can be used on floors in high traffic areas. Most epoxies develop a non-progressive chalk face on exterior exposure, but otherwise have good durability. Water based acrylic epoxies approach the durability and performance of their solvent based counterpart. They offer the added advantage of low odor and can be used over conventional paints on interior applications.

Latex

Latex paints are complex compositions of synthetic resins (usually acrylic or vinyl acrylic) and pigments kept dispersed in water by surfactants. They also contain small amounts of coalescing solvents. Latex paints dry by evaporation of the water. As water evaporates from the film, the coalescing solvents allow the particles of resin to fuse together (coalesce) forming a continuous coating. Latexes have excellent adhesion, color and gloss retention, long term flexibility, and toughness. Their advantages also include ease of application and clean up, safety, and VOC compliance. Most latex paints must be protected from freezing and applied at a minimum temperature of 50°F/10°C. Some specialty products may be applied at lower temperatures.

Silicone Alkyd

Silicone alkyd coatings begin as alkyds and are then modified with silicone resins in amounts up to 30%. Silicone alkyd paints dry, cure, and perform as alkyds, but have greatly improved color and gloss retention. They apply easily and have found widespread use in coastal areas and environments subjected to intense sunlight.

Urethane

Urethane (polyurethane) coatings are those containing an isocyanate complex. They form tough, hard, flexible, chemical resistant films by one of two methods:

Moisture curing—moisture cured urethanes dry by solvent evaporation and cure by reacting with moisture/water vapor in the air. Generally, for this to occur, relative humidity levels must exceed 20%.

Copolymerization—often called catalyzed or two component urethanes, cure by the addition of a co-reactant (catalyst) to the isocyanate-containing component. Mixing, induction time, and pot life vary according to the type of isocyanate and catalyst used.

Aliphatic Urethanes are light stable, gloss retentive, and non-yellowing. For maximum performance, they are often used over epoxy primers or zinc-rich primers with epoxy intermediate coats to protect chemical plants, bridges, water and waste water facilities, and other industrial sites.

Zinc Rich Primers

Zinc-rich primers are those containing zinc particles (generally about 80% or more by volume) in the dried film. Because zinc is a more "active" metal than steel, when exposed to aggressive chemicals or corrosive agents, the zinc will "corrode" to protect the steel substrate. This is the same protective mechanism that allows hot dipped galvanizing to minimize corrosion on steel. In order for this cathodic protection to take place, there must be direct contact between the zinc pigment particles and the steel substrate. Therefore, it is imperative that the steel be sandblasted to provide both a clean surface and a textured/roughened surface. These zinc-rich primers are available in two types:

Organic—this variety uses an organic (carbon containing) binder to "hold" the zinc pigment in the film. An organic zinc-rich primer will provide the benefits of the organic resin used (for example, epoxy), as well as the benefits of the zinc pigment.

Inorganic—this variety creates an inorganic zinc/silicate matrix on the surface of the steel. It is inorganic because there are no carbon-containing materials in the adherent film. The properties of inorganic zinc closely resemble those of the zinc metal itself: high temperature resistance and resistance to immersion in non-potable water or water with mild solutions of chemicals (pH 6-8).

By permission, Sherwin-Williams.

6.6.1 Surface Preparation for Wood, Steel Masonry

Surface Preparation



Coating performance is directly affected by surface preparation. Coating integrity and service life will be reduced because of improperly prepared surfaces. As high as 80% of all coating failures can be directly attributed to inadequate surface preparation that affects coating adhesion. Selection and implementation of the proper surface preparation ensures coating adhesion to the substrate and prolongs the service life of the coating system.

The majority of paintable surfaces are concrete, ferrous metal, galvanizing, and aluminum. They all require protection to keep them from deteriorating in aggressive environments. Selection of the proper method for surface preparation depends on the substrate, the environment, the coating selected, and the expected service life of the coating system. Economics, surface contamination, and the effect on the substrate will also influence the selection of surface preparation methods.

WARNING! Removal of old paint by sanding, scraping or other means may generate dust or fumes that contain lead. Exposure to lead dust or fumes may cause brain damage or other adverse health effects, especially in children or pregnant women. Controlling exposure to lead or other hazardous substances requires the use of proper protective equipment, such as a properly fitted respirator (NIOSH approved) and proper containment and cleanup. For more information, call the National Lead Information Center at 1-800-424-LEAD (in US) or contact your local health authority.

No exterior painting should be done immediately after a rain, during foggy weather, when rain is predicted, or when the temperature is below 50°F, unless the products to be used are designed to be used in those environments.

Aluminum S-W 1

Remove all oil, grease, dirt, oxide and other foreign material by cleaning per SSPC-SP1, Solvent Cleaning.

Block (Cinder and Concrete) S-W 3

Remove all loose mortar and foreign material. Surface must be free of laitance, concrete dust, dirt, form release agents, moisture curing membranes, loose cement, and hardeners. Concrete and mortar must be cured at least 28 days at 75°F. The pH of the surface should be between 6 and 9. On tilt-up and poured-in-place concrete, commercial detergents and abrasive blasting may be necessary to prepare the surface. Fill bug holes, air pockets, and other voids with a cement patching compound (per ASTMD4261).

Brick S-W 4

Must be free of dirt, loose and excess mortar, and foreign material. All brick should be allowed to weather for at least one year followed by wire brushing to remove efflorescence. Treat the bare brick with one coat of Loxon Conditioner or Masonry Conditioner.

Concrete and Masonry S-W 5
Concrete, Poured – Exterior or Interior

The preparation of new concrete surfaces is as important as the surface preparation of steel. The following precautions will help assure maximum performance of the coating system and satisfactory coating adhesion:

1. Cure
Concrete must be cured prior to coating. Cured is generally defined as concrete poured and aged at a material temperature of at least 75°F for at least 28 days

2. Moisture – Reference ASTM F1869-98 Moisture Test by use of Calcium Chloride or ASTM D4263 Plastic Sheet Method
Concrete must be free from moisture as much as possible (it seldom falls below 15%). Vapor pressures, temperature, humidity, differentials, and hydrostatic pressures can cause coatings to prematurely fail. The source of moisture, if present, must be located, and the cause corrected prior to coating.

3. Temperature
Air, surface and material temperatures must be in keeping with requirements for the selected product during and after coating application, until coating is cured.

4. Contamination
Remove all grease, dirt, paint, oil, laitance, efflorescence, loose mortar, and cement by the recommendations listed in the surface preparation section.

5. Surface Condition
Hollow areas, bug holes, voids, honeycombs, fin form marks, and all protrusions or rough edges are to be ground or stoned to provide a continuous surface of suitable texture for proper adhesion of the coating. Imperfections may require filling, as specified, with a recommended Sherwin-Williams product.

6. Concrete Treatment
Hardeners, sealers, form release agents, curing compounds, and other concrete treatments should be removed to ensure adequate coating adhesion and performance.

Methods of Surface Preparation on Concrete per SSPC-SP13/NACE 6 or ICRI 03732

Surface Cleaning Methods:

- Vacuum cleaning, air blast cleaning, and water cleaning per ASTM D4258. Used to remove dirt, loose material, and/or dust from concrete.
- Detergent water cleaning and steam cleaning per ASTM D4258. Used to remove oils and grease from concrete.

Prior to abrasive cleaning, and after abrasive cleaning, surfaces should be cleaned by one of the methods described above.

Mechanical Surface Preparation Methods:
Dry abrasive blasting, wet abrasive blasting, vacuum assisted abrasive blasting, and centrifugal shot abrasive blasting per ASTM D4259. Used to remove contaminants, laitance, and weak concrete, to expose subsurface voids, and to produce a sound concrete surface with adequate profile and surface porosity.

High-pressure water cleaning or water jetting per SSPC-SP12-NACE5. Used to remove contaminants, laitance, and weak concrete, to expose subsurface voids, and to produce a sound concrete surface with adequate profile and surface porosity.

6.6.1 Surface Preparation for Wood, Steel Masonry (Continued)

Surface Preparation



Impact tool methods per ASTM D4259. Used to remove existing coatings, laitance, and weak concrete. Methods include scarifying, planing, scabbling, and rotary peening. Impact tools may fracture concrete surfaces or cause microcracking requiring surface repair.

Power tool methods per ASTM D4259. Used to remove existing coatings, laitance, weak concrete, and protrusions in concrete. Methods include circular grinding, sanding, and wire brushing. These methods may not produce the required surface profile to ensure adequate adhesion of subsequent coatings.

Chemical Surface Preparation Methods:

Acid etching per ASTM D4260. Use to remove some surface contaminants, laitance, and weak concrete, and to provide a surface profile on horizontal concrete surfaces. This method requires complete removal of all reaction products and pH testing to ensure neutralization of the acid. Not recommended for vertical surfaces. Etching with hydrochloric acid shall not be used where corrosion of metal in the concrete is likely to occur. Adequate ventilation and safety equipment required.

1. Clean surface per ASTM D4268
2. Wet surface with clean water
3. Etch with 10-15% muriatic acid solution at the rate of 1 gallon per 75 square feet
4. Scrub with stiff brush
5. Allow sufficient time for scrubbing and until bubbling stops
6. If no bubbling occurs, surface is contaminated. Refer to ASTM D4258 or ASTM D4259
7. Rinse surface two or three times. Remove acid/water each time.
8. Surface should a texture similar to medium grit sandpaper.
9. Neutralize surface with a 3% solution of tri-sodium phosphate and flush with clean water.
10. Allow to dry and check for excess moisture.

Cement Composition Siding/Panels S-W 6

Remove all surface contamination by washing with an appropriate cleaner, rinse thoroughly and allow to dry. Existing peeled or checked paint should be scraped and sanded to a sound surface. Glossy surfaces should be sanded dull. Pressure clean, if needed, with a minimum of 2100 psi pressure to remove all dirt, dust, grease, oil, loose particles, laitance, foreign material, and peeling or defective coatings. Allow the surface to dry thoroughly. If the surface is new, test it for pH, many times the pH may be 10 or higher.

Copper S-W 7

Remove all oil, grease, dirt, oxide and other foreign material by cleaning per SSPC-SP2, Hand Tool Cleaning.

Drywall—Interior and Exterior S-W 8

Must be clean and dry. All nail heads must be set and spackled. Joints must be taped and covered with a joint compound. Spackled nail heads and tape joints must be sanded smooth and all dust removed prior to painting. Exterior surfaces must be spackled with exterior grade compounds.

Composition Board (Hardboard) S-W 9

Some composition boards may exude a waxy material that must be removed with a solvent prior to coating. Whether factory primed or unprimed, exterior composition board siding (hardboard) must be cleaned thoroughly and primed with an alkyd primer.

Galvanized Metal S-W 10

Allow to weather a minimum of 6 months prior to coating. Clean per SSPC-SP1 using detergent and water or a degreasing cleaner, then prime as required. When weathering is not possible or the surface has been treated with chromates or silicates, first Solvent Clean per SSPC-SP1 and apply a test area, priming as required. Allow the coating to dry at least one week before testing. If adhesion is poor, Brush Blast per SSPC-SP7 is necessary to remove these treatments.

Plaster S-W 11

Must be allowed to dry thoroughly for at least 30 days before painting. Room must be ventilated while drying; in cold, damp weather, rooms must be heated. Damaged areas must be repaired with an appropriate patching material. Bare plaster must be cured and hard. Textured, soft, porous, or powdery plaster should be treated with a solution of 1 pint household vinegar to 1 gallon of water. Repeat until the surface is hard, rinse with clear water and allow to dry.

Previously Coated Surfaces S-W 12

Maintenance painting will frequently not permit or require complete removal of all old coatings prior to repainting. However, all surface contamination such as oil, grease, loose paint, mill scale dirt, foreign matter, rust, mold, mildew, mortar, efflorescence, and sealers must be removed to assure sound bonding to the tightly adhering old paint. Glossy surfaces of old paint films must be clean and dull before repainting. Thorough washing with an abrasive cleanser will clean and dull in one operation, or, wash thoroughly and dull by sanding. Spot prime any bare areas with an appropriate primer. Recognize that any surface preparation short of total removal of the old coating may compromise the service length of the system. Check for compatibility by applying a test patch of the recommended coating system, covering at least 2 to 3 square feet. Allow to dry one week before testing adhesion per ASTM D3359. If the coating system is incompatible, complete removal is required per ASTM D4259.

Ferrous Metal Substrates
SSPC-SP1- Solvent Cleaning

Solvent cleaning is a method for removing all visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants. Solvent cleaning does not remove rust or mill scale. Change rags and cleaning solution frequently so that deposits of oil and grease are not spread over additional areas in the cleaning process. Be sure to allow adequate ventilation. For complete instructions, refer to Steel Structures Paint Council Surface Preparation Specification No.1.

6.6.1 Surface Preparation for Wood, Steel Masonry (Continued)

Surface Preparation



SSPC-SP2 - Hand Tool Cleaning

Hand Tool Cleaning removes all loose mill scale, loose rust, and other detrimental foreign matter. It is not intended that adherent mill scale, rust, and paint be removed by this process. Mil scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife. Before hand tool cleaning, remove visible oil, grease, soluble welding residues, and salts by the methods outlined in SSPC-SP1. For complete instructions, refer to Steel Structures Paint Council Surface Preparation Specification No.2.

SSPC-SP3 - Power Tool Cleaning

Power Tool Cleaning removes all loose mill scale, loose rust, and other detrimental foreign matter. It is not intended that adherent mill scale, rust, and paint be removed by this process. Mil scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife. Before power tool cleaning, remove visible oil, grease, soluble welding residues, and salts by the methods outlined in SSPC-SP1. For complete instructions, refer to Steel Structures Paint Council Surface Preparation Specification No.3.

SSPC-SP5 / NACE 1 - White Metal Blast Cleaning

A White Metal Blast Cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter. Before blast cleaning, visible deposits of oil or grease shall be removed by any of the methods specified in SSPC-SP 1 or other agreed upon methods. For complete instructions, refer to Joint Surface Preparation Standard SSPC-SP5/NACE No.1.

SSPC-SP6 / NACE 3 - Commercial Blast Cleaning

A Commercial Blast Cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter, except for staining. Staining shall be limited to no more than 33 percent of each square inch of surface area and may consist of light shadows, slight streaks, or minor discoloration caused by stains of rust, stains of mill scale, or stains of previously applied paint. Before blast cleaning, visible deposits of oil or grease shall be removed by any of the methods specified in SSPC-SP 1 or other agreed upon methods. For complete instructions, refer to Joint Surface Preparation Standard SSPC-SP6/NACE No.3.

SSPC-SP7 / NACE 4 - Brush-Off Blast Cleaning

A Brush-Off Blast Cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, loose mill scale, loose rust, and loose paint. Tightly adherent mill scale, rust, and paint may remain on the surface. Mil scale, rust, and coating are considered adherent if they cannot be removed by lifting with a dull putty knife. Before blast cleaning, visible deposits of oil or grease shall be removed by any of the methods specified in SSPC-SP 1 or other agreed upon methods. For complete instructions, refer to Joint Surface Preparation Standard SSPC-SP7/NACE No.4.

SSPC-SP10 / NACE 2 - Near-White Blast Cleaning

A Near White Blast Cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter, except for staining. Staining shall be limited to no more than 5 percent of each square inch of surface area and may consist of light shadows, slight streaks, or minor discoloration caused by stains of rust, stains of mill scale, or stains of previously applied paint. Before blast cleaning, visible deposits of oil or grease shall be removed by any of the methods specified in SSPC-SP 1 or other agreed upon methods. For complete instructions, refer to Joint Surface Preparation Standard SSPC-SP10/NACE No.2.

SSPC-SP11 - Power Tool Cleaning to Bare Metal

Metallic surfaces that are prepared according to this specification, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide corrosion products, and other foreign matter. Slight residues of rust and paint may be left in the lower portions of pits if the original surface is pitted. Prior to power tool surface preparation, remove visible deposits of oil or grease by any of the methods specified in SSPC-SP 1, Solvent Cleaning, or other agreed upon methods. For complete instructions, refer to Steel Structures Paint Council Surface Preparation Specification No.11.

SSPC-SP12 / NACE 5 - Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating

High- and Ultra-High Pressure Water Jetting for Steel and Other Hard Materials

This standard provides requirements for the use of high- and ultra-high pressure water jetting to achieve various degrees of surface cleanliness. This standard is limited in scope to the use of water only, without the addition of solid particles in the stream. For complete instructions, refer to Joint Surface Preparation Standard SSPC-SP12/NACE No.5.

SSPC-SP13 / NACE 6 or ICRI 03732 - Surface Preparation of Concrete

This standard gives requirements for surface preparation of concrete by mechanical, chemical, or thermal methods prior to the application of bonded protective coating or lining systems. The requirements of this standard are applicable to all types of cementitious surfaces including cast-in-place concrete floors and walls, precast slabs, masonry walls and shotcrete surfaces. An acceptable prepared concrete surface should be free of contaminants, laitance, loosely adhering concrete, and dust, and should provide a dry, sound, uniform substrate suitable for the application of protective coating or lining systems. Depending upon the desired finish and system, a block filler may be required. For complete instructions, refer to Joint Surface Preparation Standard SSPC-SP13/NACE No.6 or ICRI 03732

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6.6.1 Surface Preparation for Wood, Steel Masonry (Continued)

Surface Preparation



SSPC-SP14 / NACE 8 – Industrial Blast Cleaning

This standard gives requirements for industrial blast cleaning of unpainted or painted steel surfaces by the use of abrasives. This joint standard allows defined quantities of mill scale and/or old coating to remain on the surface. An industrial blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, and dirt. Traces of tightly adherent mill scale, rust, and coating residue are permitted to remain on 10% of each unit area of the surface. The traces of mill scale, rust, and coating shall be considered tightly adherent if they cannot be lifted with a dull putty knife. Shadows, streaks, and discolorations caused by stains of rust, stains of mill scale, and stains of previously applied coating may be present on the remainder of the surface.

Water Blasting S-W 21
NACE Standard RP-01-72

Removal of oil grease dirt, loose rust, loose mill scale, and loose paint by water at pressures of 2,000 to 2,500 psi at a flow of 4 to 14 gallons per minute.

Stucco S-W 22

Must be clean and free of any loose stucco. If recommended procedures for applying stucco are followed, and normal drying conditions prevail, the surface may be painted in 30 days. The pH of the surface should be between 6 and 9.

Wood—Exterior S-W 23

Must be clean and dry. Prime and paint as soon as possible. Knots and pitch streaks must be scraped, sanded, and spot primed before a full priming coat is applied. Patch all nail holes and imperfections with a wood filler or putty and sand smooth. Caulk should be applied after priming.

Wood—Interior S-W 24

All finishing lumber and flooring must be stored in dry, warm rooms to prevent absorption of moisture, shrinkage, and roughening of the wood. All surfaces must be sanded smooth, with the grain, never across it. Surface blemishes must be corrected and the area cleaned of dust before coating.

Vinyl Siding S-W 25

Vinyl siding must be cleaned thoroughly by scrubbing with a warm, soapy water solution. Rinse thoroughly.

Touch-Up, Maintenance and Repair

For a protective coating system to provide maximum long-term protection, regularly scheduled maintenance is required. Maintenance includes inspection of painted areas, cleaning of surfaces to remove oils, chemicals, and other contaminants, and touch-up of areas where the coatings have been damaged. Highly corrosive areas, such as those subjected to frequent chemical spillage, corrosive fumes, and/or high abrasion or temperature areas should be inspected frequently – every six months, for example. Areas exposed to less severe conditions, such as interiors and exteriors of potable water tanks, may be inspected annually to assess the condition of the coating system.

The SSPC-VIS 2, Standard Method for Evaluating Degree of Rusting on Painted Steel Surfaces, can be used as a guide to determine appropriate touch-up and repairs maintenance schedules. Touch-up would be suggested when the surface resembles Rust Grade 5-S (Spot Rusting), 6-G (General Rusting), or 6-P (Pinpoint Rusting). Surface preparation would generally consist of SSPC-SP2, SP3, SP11, or SP12. Overcoating a well protected, but aged steel surface showing no evidence of rusting, may be achieved by Low Pressure Water Cleaning per SSPC-SP12/WJ4, and applying an appropriate coating system.

Full removal of the existing coating system by abrasive blasting would be recommended when the surface resembles Rust Grade 3-S (Spot Rusting), 4-G (General Rusting), or 4-P (Pinpoint Rusting). When the coating system has deteriorated to encompass approximately 33% of the surface area, it is always more economical to consider full removal and reapplication of the appropriate protective coating system.

Mildew

Remove mildew before painting by washing with a solution of 1 quart liquid household bleach and 3 quarts of warm water. Apply the solution and scrub the mildewed area. Allow the solution to remain on the surface for 10 minutes. Rinse thoroughly with clean water and allow the surface to dry 48 hours before painting. Wear protective glasses or goggles, waterproof gloves, and protective clothing. Quickly wash off any of the mixture that comes in contact with your skin. Do not add detergents or ammonia to the bleach/water solution.

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6.6.2 Coating Systems for Normal Exposures

Coating systems for normal exposures



This table will help the specification writer select the best detailed specifications for normal exposures such as schools, hotels, apartments, stores, etc. as well as light, moderate, and heavy duty industrial specifications. It has been designed from the specification writer's point of view; starting with the information the specifier has—the material and the surface. The specifier can choose the coating's generic type, the finish desired, the surface preparation necessary, the appropriate primer, and the number of topcoats necessary to achieve a satisfactory coating system. Surface preparations as shown are minimums and should be upgraded if necessary because of the service or environmental conditions. For additional data on the indicated surface preparation, turn to pages 2 through 4.
For descriptions on the products, refer to the pages noted in the chart.
Note: standard alkyd and epoxy coatings will chalk on exterior exposure.

	Coating		Specifications			Minimum dft/ct		Product
Substrate/Area	Vehicle	Finish	Surface Preparation		Primers & Topcoats	mils	microns	Series
Exterior Painting Recommendations—Normal Exposure								
drywall — exterior								
Drywall	acrylic latex	primer	S-W 8, 12	1 ct:	A-100 Exterior Latex Primer	1.4	35	B42
		flat		2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
masonry and cementitious surfaces								
cementitious:	acrylic latex	primer	S-W 4, 5, 6	1 ct:	Loxon Masonry Primer, or	3.2	80	A24
panels			22, 12	1 ct:	Loxon Conditioner	none	-	A24
siding		flat		1-2 cts:	Loxon XP Waterproofing System	6.4	160	A24
shingles				2 cts:	Loxon Masonry Coating, or	3.7	93	A24
brick				2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
Concrete	latex	filler	S-W 3, 12	1 ct:	PrepRite Block Filler	8.0	200	B25
Masonry Units	acrylic latex	surfacer		1 ct:	Loxon Block Surfacer	8.0	200	A24
		flat		1-2 cts:	Loxon XP Waterproofing System	6.4	160	A24
				2 cts:	Loxon Masonry Coating, or	3.7	93	A24
				2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
elastomeric coating systems — exterior								
concrete	acrylic	primer	S-W 3, 5, 6	1 ct:	Loxon Masonry Primer	3.2	80	A24
stucco		smooth		1-2 cts:	ConFlex XL High Build, or	6.0	150	A5
CMU		texture		1-2 cts:	ConFlex XL Textured High Build	10.0	250	A5
	acrylic	surfacer	S-W 3, 12	1 ct:	Loxon Block Surfacer	8.0	200	A24
		smooth		1-2 cts:	ConFlex XL High Build, or	6.0	150	A5
		texture		1-2 cts:	ConFlex XL Textured High Build	10.0	250	A5
textured coating systems — exterior								
Textured Coating	acrylic	primer	S-W 3, 5, 6	1 ct:	Loxon Masonry Primer	3.2	80	A24
		texture		1-2 cts:	ConFlex XL Textured High Build	10.0	250	A5
	acrylic	primer	S-W 3, 5, 6	1 ct:	Loxon Masonry Primer, or	3.2	80	A24
		surfacer	S-W 3, 5, 6	1 ct:	Loxon Block Surfacer	8.0	200	A24
		texture		1-2 cts:	UltraCrete Waterborne Textured Topcoat	16.0	400	A44
	acrylic latex	surfacer	S-W 3, 5, 6	1 ct:	Loxon Block Surfacer	8.0	200	A24
	solvent borne	texture		1-2 cts:	UltraCrete Solventborne Textured Topcoat	16.0	400	A46

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6.6.2 Coating Systems for Normal Exposures (Continued)

Coating systems for normal exposures

SHERWIN-WILLIAMS.

Substrate/Area	Coating		Specifications			Minimum dft/ct		Product
	Vehicle	Finish	Surface Preparation	Primers & Topcoats		mils	microns	Series
Interior Painting Recommendations—Normal Exposure								
wood								
(continued)	alkyd	primer	S-W 24, 12	1 ct:	PrepRite Wall and Wood Primer, or	1.9	48	B49
	latex			1 ct:	PrepRite Classic Latex Primer	1.6	40	B28
		eg-shel		2 cts:	ProClassic Int. Alkyd Satin, or	1.8	45	B33
				2 cts:	ProMar 200 Int. Alkyd Eg-Shel, or	1.8	45	B33
		semi-gloss		2 cts:	ProClassic XP Int. Alkyd Semi-Gloss, or	3.2	80	B34
				2 cts:	ProClassic Int. Alkyd Semi-Gloss, or	1.6	40	B34
				2 cts:	ProMar 200 or 400 Int. Alkyd S/G, or	1.7	43	B34
		gloss		2 cts:	ProMar 200 Int. Alkyd Gloss	1.5	38	B35
low odor finish	latex	primer	S-W 1, 12	1 ct:	Harmony Low Odor Latex Primer, or	1.3	33	B11
					ProGreen 200 Low VOC Primer	1.5	38	B28
		flat		2 cts:	Harmony Low Odor Latex Flat, or	1.7	43	B05
					ProGreen 200 Low VOC Flat, or	1.8	45	B30
		eg-shel		2 cts:	Harmony Low Odor Latex Eg-Shel, or	1.6	40	B09
					ProGreen 200 Low VOC Eg-Shel, or	1.7	42	B20
		semi-gloss		2 cts:	Harmony Low Odor Latex Semi-Gloss, or	1.6	40	B10
					ProGreen 200 Low VOC Semi-Gloss	1.6	40	B31
Clear Finishes	alkyd	stain	S-W 24, 12	1 ct:	Wood Classics Oil Stain (optional)	none	-	A49
Varnishes	alkyd	sealer		1 ct:	Wood Classics Sanding Sealer (optional)	1.0	25	B26
		satin/gloss		2 cts:	Wood Classics Oil Base Varnish	1.3	33	A66
	alkyd	stain	S-W 24, 12	1 ct:	Wood Classics Oil Stain (optional)	none	-	A49
	wb poly.	satin/gloss		2 cts:	Wood Classics Waterborne Polyurethane	1.0	25	A68
hard wear surfaces	alkyd	gloss	S-W 24, 12	1 ct:	Wood Classics Oil Stain (optional)	none	-	A49
	polyurethane	satin/gloss		2 cts:	Wood Classics Polyurethane	1.7	43	A67
Floor surfaces (No Vehicle Traffic)								
wood	acrylic	gloss	S-W 23, 12	1-2 cts:	Porch & Floor Enamel	1.4	35	A32
	alkyd	gloss	S-W 24, 12	1 ct:	Wood Classics Oil Stain (optional)	none	-	A49
	polyurethane	satin/gloss		2 cts:	Wood Classics Polyurethane	1.7	43	A67
concrete	acrylic	gloss	S-W 23, 12	1-2 cts.	ArmorSeal 1K WB Urethane Floor Enamel , or	2.0	50	B65
				1-2 cts:	Porch & Floor Enamel	1.4	35	A32
	acrylic stain	flat	S-W 5, 12	1-2 cts:	H&C Shield Plus Ultra Concrete Stain	none	-	-
Specialty								
emissivity barrier	copolymer	metallic	substrate dependant	1 ct:	E-Barrier Reflective Coating	0.3	7.5	B68

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6.6.2 Coating Systems for Normal Exposures (Continued)

Coating systems for normal exposures								SHERWIN-WILLIAMS
Substrate/Area	Coating		Specifications			Minimum dft/ct		Product
	Vehicle	Finish	Surface Preparation	Primers & Topcoats		mils	microns	Series
Interior Painting Recommendations—Normal Exposure								
Plaster								
Walls Ceilings	acrylic epoxy	primer eg-shel semi-gloss	S-W 8, 12	1 ct: 2 cts: 2 cts:	PrepRite Masonry Primer ProIndustrial Precat. WB Epoxy, Eg-Shel ProIndustrial Precat. WB Epoxy, S-G	3.0 1.5 1.5	75 38 38	A24 K45 K46
	acrylic alkyd latex	primer	S-W 11, 12	1 ct: 1 ct: 1 ct:	PrepRite Masonry Primer PrepRite Wall and Wood Primer, or PrepRite Classic Latex Primer, or	3.0 1.9 1.6	75 48 40	A24 B49 B28
		flat		2 cts: 2 cts: 2 cts:	Duration Home Int. Latex Matte, or Cashmere Int. Latex Flat, or ProMar 200 or 400 Int. Latex Flat, or	1.6 1.6 1.3	40 40 33	A96 D16 B30
		low luster		2 cts:	Cashmere Int. Latex Low Lustre, or	1.4	35	D17
		satin		2 cts: 2 cts:	Duration Home Int. Latex Satin, or ProClassic Waterborne Satin, or	1.5 1.3	38 33	A97 B20
		eg-shel		2 cts: 2 cts:	ProMar 200 Int Latex Low Sheen ES, or ProMar 200 or 400 Int. Latex Eg-Shel, or	1.5 1.6	38 40	B20 B20
		med. luster		2 cts:	Cashmere Int. Latex Medium Lustre, or	1.5	38	D18
		semi-gloss		2 cts: 2 cts: 2 cts:	Duration Home Int. Latex Semi-Gloss, or ProClassic Waterborne Semi-Gloss, or ProMar 200 or 400 Latex Semi-Gloss, or	1.4 1.4 1.5	35 35 38	A98 B31 B31
		gloss		2 cts: 2 cts:	ProClassic Waterborne Gloss, or ProMar 200 or 400 Int. Latex Gloss, or	1.6 1.5	40 38	B21 B21
		high gloss		2 cts:	ProClassic Waterborne High Gloss	1.5	38	B21
	acrylic alkyd	primer	S-W 11, 12	1 ct: 1 ct: 1 ct:	PrepRite Classic Latex Primer, or PrepRite Masonry Primer, or PrepRite Wall and Wood Primer	1.6 3.0 1.9	40 75 48	B28 B28 B49
		eg-shel		2 cts: 2 cts:	ProClassic Int. Alkyd Satin, or ProMar 200 Int. Alkyd Eg-Shel, or	1.8 1.8	45 45	B33 B33
		semi-gloss		2 cts: 2 cts: 2 cts:	ProClassic XP Int. Alkyd Semi-Gloss, or ProClassic Int. Alkyd Semi-Gloss, or ProMar 200 or 400 Int. Alkyd S/G, or	3.2 1.6 1.7	80 40 43	B34 B34 B34
		gloss		2 cts:	ProMar 200 Int. Alkyd Gloss	1.5	38	B35
low odor finish	latex	primer	S-W 11, 12	1 ct:	Harmony Low Odor Latex Primer, or ProGreen 200 Low VOC Primer	1.3 1.5	33 38	B11 B28
		flat		2 cts:	Harmony Low Odor Latex Flat, or ProGreen 200 Low VOC Flat, or	1.7 1.8	43 45	B05 B30
		eg-shel		2 cts:	Harmony Low Odor Latex Eg-Shel, or ProGreen 200 Low VOC Eg-Shel, or	1.6 1.7	40 42	B09 B20
		semi-gloss		2 cts:	Harmony Low Odor Latex Semi-Gloss, or ProGreen 200 Low VOC Semi-Gloss	1.6 1.6	40 40	B10 B31
wood								
walls doors trim window	acrylic epoxy	primer eg-shel semi-gloss	S-W 24, 12	1 ct: 2 cts: 2 cts:	PrepRite Masonry Primer ProIndustrial Precat. WB Epoxy, Eg-Shel ProIndustrial Precat. WB Epoxy, S-G	3.0 1.5 1.5	75 38 38	A24 K45 K46
	alkyd latex	primer	S-W 24, 12	1 ct: 1 ct:	PrepRite Wall and Wood Primer, or PrepRite Classic Latex Primer	1.9 1.6	48 40	B49 B28
		flat		2 cts: 2 cts: 1-2 cts: 2 cts:	Duration Home Int. Latex Matte, or Cashmere Int. Latex Flat, or ProMar 200 XP Interior Latex Flat, or ProMar 200 or 400 Int. Latex Flat, or	1.6 1.6 4.6 1.3	40 40 115 33	A96 D16 B30 B30
		low luster		2 cts:	Cashmere Int. Latex Low Lustre, or	1.4	35	D17
		satin		2 cts: 2 cts:	Duration Home Int. Latex Satin, or ProClassic Waterborne Satin, or	1.5 1.3	38 33	A97 B20
		eg-shel		1-2 cts: 2 cts: 2 cts:	ProMar 200 XP Interior Latex Eg-Shel, or ProMar 200 Int Latex Low Sheen ES, or ProMar 200 or 400 Int. Latex Eg-Shel, or	4.6 1.5 1.6	115 38 40	B20 B20 B20
		med. luster		2 cts:	Cashmere Int. Latex Medium Lustre, or	1.5	38	D18
		semi-gloss		2 cts: 2 cts: 2 cts:	Duration Home Int. Latex Semi-Gloss, or ProClassic Waterborne Semi-Gloss, or ProMar 200 or 400 Latex Semi-Gloss, or	1.4 1.4 1.5	35 35 38	A98 B31 B31
		gloss		2 cts: 2 cts:	ProClassic Waterborne Gloss, or ProMar 200 or 400 Int. Latex Gloss, or	1.6 1.5	40 38	B21 B21
		high gloss		2 cts:	ProClassic Waterborne High Gloss	1.5	38	B21

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6.6.2 Coating Systems for Normal Exposures (Continued)

Coating systems for normal exposures — SHERWIN-WILLIAMS

Substrate/Area	Coating: Vehicle	Coating: Finish	Specifications: Surface Preparation	Specifications: Primers & Topcoats	Minimum dft/ct: mils	Minimum dft/ct: microns	Product Series
Interior Painting Recommendations—Normal Exposure							
drywall — interior							
low odor finish	latex	primer	S-W 8, 12	1 ct: Harmony Low Odor Latex Primer, or	1.3	33	B11
				ProGreen 200 Low VOC Primer	1.5	38	B28
		flat		2 cts: Harmony Low Odor Latex Flat, or	1.7	43	B05
				ProGreen 200 Low VOC Flat, or	1.8	45	B30
		eg-shel		2 cts: Harmony Low Odor Latex Eg-Shel, or	1.6	40	B09
				ProGreen 200 Low VOC Eg-Shel, or	1.7	42	B20
		semi-gloss		2 cts: Harmony Low Odor Latex Semi-Gloss, or	1.6	40	B10
				ProGreen 200 Low VOC Semi-Gloss	1.6	40	B31
Gypsum Board	latex	primer	S-W 8, 12	1 ct: PrepRite Classic Latex Primer, or	1.6	40	B28
Plaster Board	alkyd	eg-shel		2 cts: ProClassic Int. Alkyd Satin, or	1.8	45	B33
				2 cts: ProMar 200 Int. Alkyd Eg-Shel, or	1.8	45	B33
		semi-gloss		2 cts: ProClassic XP Int. Alkyd Semi-Gloss, or	3.2	80	B34
				2 cts: ProClassic Int. Alkyd Semi-Gloss, or	1.6	40	B34
				2 cts: ProMar 200 or 400 Int. Alkyd S/G, or	1.7	43	B34
		gloss		2 cts: ProMar 200 Int. Alkyd Gloss	1.5	38	B35
ceilings	latex	primer	S-W 8, 12	1 ct: PrepRite 200 Int Latex Primer	1.1	28	B28
	alkyd			1 ct: Super Save Lite Hi-Tec Dryfall, or	1.5	38	B48
				1 ct: Super Save Lite Dryfall	3.0	75	B48
masonry and cementitious surfaces							
concrete	latex	primer	S-W 8, 12	1 ct: PrepRite 200 Int Latex Primer	1.1	28	B28
cement board	epoxy	eg-shel		2 cts: ProIndustrial Precat. WB Epoxy, Eg-Shel	1.5	38	K45
CMU		semi-gloss		2 cts: ProIndustrial Precat. WB Epoxy, S-G	1.5	38	K46
block							
brick (unglazed)	acrylic	primer	S-W 5, 3, 4,	1 ct: PrepRite Masonry Primer, or	3.0	75	B28
		surfacer	or 12	1 ct: PrepRite High Build Surfacer, or	4.4	110	A24
				1 ct: Loxon Block Surfacer	8.0	200	A24
	latex	flat		2 cts: Duration Home Int. Latex Matte, or	1.6	40	A96
				2 cts: Cashmere Int. Latex Flat, or	1.6	40	D16
				1-2 cts: ProMar 200 XP Interior Latex Flat, or	4.6	115	B30
				2 cts: ProMar 200 or 400 Int. Latex Flat, or	1.3	33	B30
		low luster		2 cts: Cashmere Int. Latex Low Lustre, or	1.4	35	D17
		satin		2 cts: Duration Home Int. Latex Satin, or	1.5	38	A97
				2 cts: ProClassic Waterborne Satin, or	1.3	33	B20
		eg-shel		1-2 cts: ProMar 200 XP Interior Latex Eg-Shel, or	4.6	115	B20
				2 cts: ProMar 200 Int Latex Low Sheen ES, or	1.5	38	B20
				2 cts: ProMar 200 or 400 Int. Latex Eg-Shel, or	1.6	40	B20
		med. luster		2 cts: Cashmere Int. Latex Medium Lustre, or	1.5	38	D18
		semi-gloss		2 cts: Duration Home Int. Latex Semi-Gloss, or	1.4	35	A98
				2 cts: ProClassic Waterborne Semi-Gloss, or	1.4	35	B31
				2 cts: ProMar 200 or 400 Latex Semi-Gloss, or	1.5	38	B31
		gloss		2 cts: ProClassic Waterborne Gloss, or	1.6	40	B21
				2 cts: ProMar 200 or 400 Int. Latex Gloss	1.5	38	B21
		high gloss		2 cts: ProClassic Waterborne High Gloss	1.5	38	B21
	acrylic	primer	S-W 5, 3, 4,	1 ct: PrepRite Masonry Primer, or	3.0	75	A24
		filler	or 12	1 ct: Loxon Block Surfacer	8.0	200	A24
	alkyd	eg-shel		2 cts: ProClassic Int. Alkyd Satin, or	1.8	45	B33
				2 cts: ProMar 200 Int. Alkyd Eg-Shel, or	1.8	45	B33
		semi-gloss		2 cts: ProClassic XP Int. Alkyd Semi-Gloss, or	3.2	80	B34
				2 cts: ProClassic Int. Alkyd Semi-Gloss, or	1.6	40	B34
				2 cts: ProMar 200 or 400 Int. Alkyd S/G, or	1.7	43	B34
		gloss		2 cts: ProMar 200 Int. Alkyd Gloss	1.5	38	B35
low odor finish	latex	primer	S-W 8, 12	1 ct: Harmony Low Odor Latex Primer, or	1.3	33	B11
			or 12	ProGreen 200 Low VOC Primer	1.5	38	B28
		flat		2 cts: Harmony Low Odor Latex Flat, or	1.7	43	B05
				ProGreen 200 Low VOC Flat, or	1.8	45	B30
		eg-shel		2 cts: Harmony Low Odor Latex Eg-Shel, or	1.6	40	B09
				ProGreen 200 Low VOC Eg-Shel, or	1.7	42	B20
		semi-gloss		2 cts: Harmony Low Odor Latex Semi-Gloss, or	1.6	40	B10
				ProGreen 200 Low VOC Semi-Gloss	1.6	40	B31

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6.6.2 Coating Systems for Normal Exposures (Continued)

Coating systems for normal exposures

SHERWIN-WILLIAMS.

Substrate/Area	Coating		Specifications			Minimum dft/ct		Product
	Vehicle	Finish	Surface Preparation	Primers & Topcoats		mils	microns	Series
Interior Painting Recommendations—Normal Exposure								
metal								
aluminum	acrylic	primer	S-W 8, 12	1 ct:	DTM Acrylic Primer	2.5	62	B66
	epoxy	eg-shel		2 cts:	ProIndustrial Precat. WB Epoxy, Eg-Shel	1.5	38	K45
		semi-gloss		2 cts:	ProIndustrial Precat. WB Epoxy, S-G	1.5	38	K46
	acrylic	primer	S-W 1 or 12	1 ct:	All Surface Enamel Latex Primer	2.5	63	A41
	latex	flat		2 cts:	Cashmere Int. Latex Flat, or	1.6	40	D16
				2 cts:	ProMar 200 or 400 Int. Latex Flat, or	1.3	33	B30
		flat		2 cts:	Duration Home Int. Latex Matte, or	1.6	40	A96
				2 cts:	Cashmere Int. Latex Flat, or	1.6	40	D16
				1-2 cts:	ProMar 200 XP Interior Latex Flat, or	4.6	115	B30
		satin		2 cts:	ProClassic Waterborne Satin, or	1.3	33	B20
		eg-shel		1-2 cts:	ProMar 200 XP Interior Latex Eg-Shel, or	4.6	115	B20
				2 cts:	ProMar 200 Int Latex Low Sheen ES, or	1.5	38	B20
				2 cts:	ProMar 200 or 400 Int. Latex Eg-Shel, or	1.6	40	B20
		med. luster		2 cts:	Cashmere Int. Latex Medium Lustre, or	1.5	38	D18
		satin		2 cts:	Duration Home Int. Latex Satin, or	1.5	38	A97
				2 cts:	ProClassic Waterborne Satin, or	1.3	33	B20
		semi-gloss		2 cts:	Duration Home Int. Latex Semi-Gloss, or	1.4	35	A98
				2 cts:	ProClassic Waterborne Semi-Gloss, or	1.4	35	B31
				2 cts:	ProMar 200 or 400 Latex Semi-Gloss, or	1.5	38	B31
		gloss		2 cts:	ProClassic Waterborne Gloss, or	1.6	40	B21
				2 cts:	ProMar 200 or 400 Int. Latex Gloss	1.5	38	B21
		high gloss		2 cts:	ProClassic Waterborne High Gloss	1.5	38	B21
	acrylic	primer	S-W 1 or 12	1 ct:	Pro-Cryl Universal Primer, White	2.0	50	B66
	alkyd	eg-shel		2 cts:	ProClassic Int. Alkyd Satin, or	1.8	45	B33
				2 cts:	ProMar 200 Int. Alkyd Eg-Shel, or	1.8	45	B33
		semi-gloss		2 cts:	ProClassic XP Int. Alkyd Semi-Gloss, or	3.2	80	B34
				2 cts:	ProClassic Int. Alkyd Semi-Gloss, or	1.6	40	B34
				2 cts:	ProMar 200 or 400 Int. Alkyd S/G, or	1.7	43	B34
		gloss		2 cts:	ProMar 200 Int. Alkyd Gloss	1.5	38	B35
galvanized	acrylic	primer	S-W 8, 12	1 ct:	DTM Acrylic Primer	2.5	62	B66
	epoxy	eg-shel		2 cts:	ProIndustrial Precat. WB Epoxy, Eg-Shel	1.5	38	K45
		semi-gloss		2 cts:	ProIndustrial Precat. WB Epoxy, S-G	1.5	38	K46
	acrylic	primer	S-W 10, 12	1 ct:	All Surface Enamel Latex Primer	2.5	63	A41
	latex	flat		2 cts:	Duration Home Int. Latex Matte, or	1.6	40	A96
				2 cts:	Cashmere Int. Latex Flat, or	1.6	40	D16
				1-2 cts:	ProMar 200 XP Interior Latex Flat, or	4.6	115	B30
				2 cts:	ProMar 200 or 400 Int. Latex Flat, or	1.3	33	B30
		low luster		2 cts:	Cashmere Int. Latex Low Lustre, or	1.4	35	D17
		satin		2 cts:	Duration Home Int. Latex Satin, or	1.5	38	A97
				2 cts:	ProClassic Waterborne Satin, or	1.3	33	B20
		eg-shel		1-2 cts:	ProMar 200 XP Interior Latex Eg-Shel, or	4.6	115	B20
				2 cts:	ProMar 200 Int Latex Low Sheen ES, or	1.5	38	B20
				2 cts:	ProMar 200 or 400 Int. Latex Eg-Shel, or	1.6	40	B20
		med. luster		2 cts:	Cashmere Int. Latex Medium Lustre, or	1.5	38	D18
		semi-gloss		2 cts:	Duration Home Int. Latex Semi-Gloss, or	1.4	35	A98
				2 cts:	ProClassic Waterborne Semi-Gloss, or	1.4	35	B31
				2 cts:	ProMar 200 or 400 Latex Semi-Gloss, or	1.5	38	B31
		gloss		2 cts:	ProClassic Waterborne Gloss, or	1.6	40	B21
				2 cts:	ProMar 200 or 400 Int. Latex Gloss, or	1.5	38	B21
		high gloss		2 cts:	ProClassic Waterborne High Gloss	1.5	38	B21
	acrylic	primer	S-W 10, 12	1 ct:	Pro-Cryl Universal Primer, White	2.0	50	B66
	alkyd	eg-shel		2 cts:	ProClassic Int. Alkyd Satin, or	1.8	45	B33
				2 cts:	ProMar 200 Int. Alkyd Eg-Shel, or	1.8	45	B33
		semi-gloss		2 cts:	ProClassic XP Int. Alkyd Semi-Gloss, or	3.2	80	B34
				2 cts:	ProClassic Int. Alkyd Semi-Gloss, or	1.6	40	B34
				2 cts:	ProMar 200 or 400 Int. Alkyd S/G, or	1.7	43	B34
		gloss		2 cts:	ProMar 200 Int. Alkyd Gloss	1.5	38	B35

6.6.2 Coating Systems for Normal Exposures (Continued)

Coating systems for normal exposures — SHERWIN-WILLIAMS.

Substrate/Area	Coating		Specifications			Minimum dft/ct		Product
	Vehicle	Finish	Surface Preparation	Primers & Topcoats		mils	microns	Series
Exterior Painting Recommendations—Normal Exposure								
stains, sealers, waterproofers for masonry								
Pigmented	acrylic	flat	S-W 5, 12	2 cts:	Sher-Crete Flexible Concrete Waterproofer	14.0	350	A5
	acrylic	none	S-W 5, 12	1-2 cts:	Vertical Concrete Stain	none	-	A31
	acrylic stain	flat	S-W 5, 12	1-2 cts:	H&C Shield Plus Ultra Concrete Stain	none	-	-
	silicone acrylic sealer	none	S-W 5, 12	1-2 cts:	H&C Silicone Acrylic Concrete Sealer	none	-	-
Clear	silane	none	S-W 5, 12	1-2 cts:	Loxon Silane Water Repellant	none	-	A31
	siloxane	none	S-W 5, 12	1-2 cts:	Loxon Siloxane Water Repellant	none	-	A10
metal								
Aluminum Siding and trim	acrylic latex	flat	S-W 1, 12	2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
Iron and Steel	alkyd	primer	SSPC-SP2 or SW 12	1 ct:	All Surface Enamel Oil Primer, or	2.0	50	A11
	acrylic latex			1 ct:	All Surface Enamel Latex Primer	2.5	63	A41
		flat		2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
Galvanized	acrylic latex	primer	S-W 10, 12	1 ct:	All Surface Enamel Latex Primer	2.5	63	A41
		flat		2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
wood								
Siding and Trim Paint	alkyd	primer	S-W 23, 12	1 ct:	A-100 Exterior Oil Primer, or	2.3	58	Y24
	acrylic latex			1 ct:	A-100 Exterior Latex Primer	1.4	35	B42
		flat		2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85
Plywood Paint	acrylic latex	primer	S-W 23, 12	1 ct:	A-100 Exterior Latex Primer	1.4	35	B42
		flat		2 cts:	Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts:	A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts:	Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts:	A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts:	Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts:	A-100 Exterior Latex Gloss, or	1.3	33	A8
		high gloss		2 cts:	SuperPaint Exterior Latex High Gloss	1.3	33	A85

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6.6.2 Coating Systems for Normal Exposures (Continued)

Coating systems for normal exposures — SHERWIN-WILLIAMS.

Substrate/Area	Coating: Vehicle	Coating: Finish	Specifications: Surface Preparation	Specifications: Primers & Topcoats	Minimum dft/ct: mils	Minimum dft/ct: microns	Product Series
Exterior Painting Recommendations—Normal Exposure							
wood - vertical surfaces							
stain solid color	acrylic	solid	S-W 23, 12	2 cts: WoodScapes Solid Color Stain	2.0	50	A15
semi-transparent	polyurethane	semi-trans	S-W 23, 12	2 cts: WoodScapes Semi-Transparent, or	none	-	A15
	alkyd	clear	S-W 23, 12	1-2 cts: Exterior Alkyd Semi-Transparent Stain	none	-	-
vinyl siding and trim							
	acrylic latex	flat	S-W 25, 12	2 cts: Duration Exterior Latex Flat Coating, or	2.8	70	K32
				2 cts: A-100 Exterior Latex Flat, or	1.2	30	A6
		satin		2 cts: Duration Exterior Latex Satin Coating, or	2.8	70	K33
				2 cts: A-100 Exterior Latex Satin, or	1.3	33	A82
		gloss		2 cts: Duration Exterior Latex Gloss Coating, or	2.8	70	K34
				2 cts: A-100 Exterior Latex Gloss	1.3	33	A8
Floor Surfaces (No Vehicle Traffic)							
wood	acrylic	flat	S-W 23, 12	1-2 cts: DeckScapes Ext. Solid Color Deck Stain	2.0	50	-
	water borne	clear	S-W 23, 12	1-2 cts: DeckScapes Ext. Waterborne Clear, or	none	-	-
		semi-trans		1-2 cts: DeckScapes Ext. WB Semi-Trans Stain, or	none	-	-
		toner		1-2 cts: DeckScapes Ext. Waterborne Toner	none	-	-
	solvent borne	semi-trans		1-2 cts: DeckScapes Ext. Oil Semi-Trans Stain, or	none	-	-
		toner		1-2 cts: DeckScapes Ext. Oil Toner	none	-	-
concrete - pigmented	acrylic	flat	S-W 5, 12	2 cts: Sher-Crete Flexible Concrete Waterproofer	14.0	350	A5
	acrylic stain	flat	S-W 5, 12	1-2 cts: H&C Shield Plus Ultra Concrete Stain	none	-	-
	silicone acrylic	none	S-W 5, 12	1-2 cts: H&C Silicone Acrylic Concrete Sealer	none	-	-
	acrylic	gloss	S-W 23, 12	1-2 cts: Porch & Floor Enamel	1.4	35	A32
- clear	silane	none	S-W 5, 12	1-2 cts: Loxon 40% Silane Water Repellant	none	-	A31
	siloxane	none	S-W 5, 12	1-2 cts: Loxon 7% Siloxane Water Repellant	none	-	A10
Interior Painting Recommendations—Normal Exposure							
drywall — interior							
Gypsum Board	latex	primer	S-W 8, 12	1 ct: PrepRite 200 Int Latex Primer	1.1	28	B28
Plaster Board	epoxy	eg-shel		2 cts: ProIndustrial Precat. WB Epoxy, Eg-Shel	1.5	38	K45
light industrial		semi-gloss		2 cts: ProIndustrial Precat. WB Epoxy, Semi-Gloss	1.5	38	K46
Gypsum Board	latex	primer	S-W 8, 12	1 ct: PrepRite Classic Latex Primer, or	1.6	40	B28
Plaster Board				1 ct: PrepRite 200 Int Latex Primer	1.1	28	B28
		flat		2 cts: Duration Home Int. Latex Matte, or	1.6	40	A96
				2 cts: Cashmere Int. Latex Flat, or	1.6	40	D16
				1-2 cts: ProMar 200 XP Interior Latex Flat, or	4.6	115	B30
				2 cts: ProMar 200 or 400 Int. Latex Flat, or	1.3	33	B30
		low luster		2 cts: Cashmere Int. Latex Low Lustre, or	1.4	35	D17
		satin		2 cts: Duration Home Int. Latex Satin, or	1.5	38	A97
				2 cts: ProClassic Waterborne Satin, or	1.3	33	B20
		eg-shel		1-2 cts: ProMar 200 XP Interior Latex Eg-Shel, or	4.6	115	B20
				2 cts: ProMar 200 Int Latex Low Sheen ES, or	1.5	38	B20
				2 cts: ProMar 200 or 400 Int. Latex Eg-Shel, or	1.6	40	B20
		med. luster		2 cts: Cashmere Int. Latex Medium Lustre, or	1.5	38	D18
		semi-gloss		2 cts: Duration Home Int. Latex Semi-Gloss, or	1.4	35	A98
				2 cts: ProClassic Waterborne Semi-Gloss, or	1.4	35	B31
				2 cts: ProMar 200 or 400 Latex Semi-Gloss, or	1.5	38	B31
		gloss		2 cts: ProClassic Waterborne Gloss, or	1.6	40	B21
				2 cts: ProMar 200 or 400 Int. Latex Gloss, or	1.5	38	B21
		high gloss		2 cts: ProClassic Waterborne High Gloss	1.5	38	B21

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6.6.3 Coating Systems for Commercial Facilities

Systems Selection Guide - Commercial Facilities — SHERWIN-WILLIAMS.

PAINTING SCHEDULE	SYSTEM TYPE	SURFACE PREPARATION	PRIMER bare/unpainted	INTERMEDIATE 1st Coat	TOPCOAT 2nd Coat If necessary
GYPSUM BOARD - Commercial/High Performance					
Interior Offices/Hallways/ Conference Rooms	Acrylic	Clean & Dry	PrepRite 200 Latex Primer	ProMar 200 Latex Eg-Shel	ProMar 200 Latex Eg-Shel
Interior Cafeteria/ High Traffic Areas	Acrylic	Clean & Dry	PrepRite 200 Latex Primer	ProMar 200 Latex Semi-Gloss	ProMar 200 Latex Semi-Gloss
GYPSUM BOARD - Industrial/High Performance					
Interior Restrooms/Kitchen/ Shower Rooms (Low Odor)	Waterbased Epoxy	Clean & Dry	PrepRite 200 Latex Primer	Hi-Bild WB Catalyzed Epoxy	Hi-Bild WB Catalyzed Epoxy
Interior Production Areas/ High Traffic Areas	Epoxy	Clean & Dry	PrepRite 200 Latex Primer	Tile-Clad HS Epoxy	Tile-Clad HS Epoxy
Interior Misc Gypsum Board/Moisture & Chemical Resistant (Low Odor)	Waterbased Epoxy	Clean & Dry	PrepRite 200 Latex Primer	Waterbased Tile-Clad Epoxy	Waterbased Tile-Clad Epoxy
Interior Misc Gypsum Board/Moisture & Chemical Resistant (Low Odor)	Epoxy	Clean & Dry	PrepRite 200 Latex Primer	Macropoxy 646 Epoxy	Macropoxy 646 Epoxy
PLASTER					
Interior Misc Plaster	Acrylic	Clean & Dry	PrepRite Masonry Primer	ProMar 200 Latex Eg-Shel	ProMar 200 Latex Eg-Shel
CONCRETE BLOCK - Commercial/High Performance					
Interior Block Walls	Acrylic	SSPC SP13	PrepRite Int/Ext Block Filler	ProMar 200 Latex Semi-Gloss	ProMar 200 Latex Semi-Gloss
Exterior Block Walls	Acrylic	SSPC SP13	Heavy Duty Block Filler	DTM Acrylic Coating	DTM Acrylic Coating
CONCRETE BLOCK - Industrial/High Performance					
Interior Moisture & Chemical Resistant (Low Odor)	Waterbased Epoxy	SSPC SP13	Heavy Duty Block Filler	Waterbased Tile-Clad Epoxy	Waterbased Tile-Clad Epoxy
Interior Moisture & Chemical Resistant	Epoxy	SSPC SP13	Heavy Duty Block Filler	Macropoxy 646 Epoxy	Macropoxy 646 Epoxy
CONCRETE MASONRY UNITS					
Interior CMU	Acrylic	SSPC SP13	PrepRite Masonry Primer	ProMar 200 Latex Semi-Gloss	ProMar 200 Latex Semi-Gloss
Exterior CMU	Acrylic	SSPC SP13	Loxon Acrylic Masonry Primer	DTM Acrylic Coating	DTM Acrylic Coating
INTERIOR CEILING/DECKING					
Interior Galvanized - Bare/Primed/ Painted	Acrylic	SSPC SP1	Waterbased Acrylic Dryfall	Waterbased Acrylic Dryfall	
Interior Steel - Bare/Primed/ Painted	Alkyd	SSPC SP1	Alkyd Dryfall	Alkyd Dryfall	
INTERIOR CONCRETE FLOORS					
Interior Light Industrial/ Foot Traffic	Acrylic	SSPC SP13	ArmorSeal TreadPlex Primer	ArmorSeal TreadPlex Coating	ArmorSeal TreadPlex Coating
Interior Moderate Industrial/ Foot Traffic	Waterbased Epoxy	SSPC SP13	ArmorSeal 7100 Epoxy Primer	ArmorSeal 7100 Epoxy	ArmorSeal 7100 Epoxy
Interior Heavy Industrial/ Vehicular Traffic	100% Solids Epoxy	SSPC SP13	ArmorSeal 33 Primer Primer	ArmorSeal 650 SL/RC Epoxy	

Always refer to product data page for additional information on surface preparation, application, environmental conditions, product uses and limitations.

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6.6.4 Coating Systems for Industrial Facilities

Systems Selection Guide - Industrial Facilities — SHERWIN-WILLIAMS.

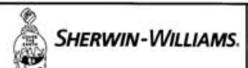
PAINTING SCHEDULE	SYSTEM TYPE	SURFACE PREPARATION	PRIMER bare/unpainted	INTERMEDIATE 1st Coat	TOPCOAT 2nd Coat If necessary
STEEL - Commercial/High Performance					
Interior Handrails/Doors/Frames/ Piping/Machinery (Low Odor)	Waterbased Acrylic/Alkyd	SSPC SP2 / SP3	ProCryl Universal Primer	Waterbased Industrial Enamel	Waterbased Industrial Enamel
Interior Handrails/Doors/Frames/ Piping/Machinery	Alkyd	SSPC SP2 / SP3	Kem Bond HS Primer	Industrial Enamel	Industrial Enamel
Interior/Exterior Misc Structural (Low Odor)	Acrylic	SSPC SP2 / SP3	ProCryl Universal Primer	DTM Acrylic Coating	DTM Acrylic Coating
Exterior Handrails/Doors/Frames	Alkyd	SSPC SP2 / SP3	Kem Bond HS Primer Alkyd	Industrial Urethane Alkyd	Industrial Urethane
Exterior Misc Structural Steel	Waterbased Acrylic/ Urethane	SSPC SP2 / SP3	ProCryl Universal Primer	HydroGloss WB Urethane	HydroGloss WB Urethane
STEEL - Industrial/High Performance					
Interior Piping/Tanks/Misc Structural (Low Odor)	Waterbased Epoxy	SSPC SP2 / SP3	Waterbased Tile-Clad Primer	Waterbased Tile-Clad Epoxy	Waterbased Tile-Clad Epoxy
Interior Piping/Tanks/Misc Structural	Epoxy	SSPC SP2 / SP3	Macropoxy 646 Epoxy	Macropoxy 646 Epoxy	Macropoxy 646 Epoxy
Exterior Piping/Tanks/Misc Structural	Epoxy/Urethane	SSPC SP6	Macropoxy 646 Epoxy	Hi-Solids Polyurethane	Hi-Solids Polyurethane
Exterior Piping/Tanks/Misc Structural	Waterbased Epoxy/ Urethane	SSPC SP6	Waterbased Tile-Clad Primer	HydroGloss WB Urethane	HydroGloss WB Urethane
GALVANIZED STEEL					
Interior Handrails/Piping/ Misc (Low Odor)	Waterbased Acrylic/Alkyd	SSPC SP1	ProCryl Universal Primer	Waterbased Industrial Enamel	Waterbased Industrial Enamel
Interior Ductwork (Low Odor)	Acrylic	SSPC SP1	ProCryl Universal Primer	DTM Acrylic Coating	DTM Acrylic Coating
Interior Misc Galvanized	Acrylic/Alkyd	SSPC SP1	Galvite HS	Industrial Enamel	Industrial Enamel
Exterior Misc Galvanized	Acrylic/Alkyd	SSPC SP1	Galvite HS Alkyd	Industrial Urethane Alkyd	Industrial Urethane
ALUMINUM					
Interior/Exterior Prefinished Siding	Acrylic	SSPC SP1	BondPlex	BondPlex	
Interior/Exterior Bare Aluminum	Acrylic	SSPC SP1	DTM Wash Primer	DTM Acrylic Coating	DTM Acrylic Coating
WOOD					
Interior Doors/Trim - Painted	Alkyd	Clean & Dry	PrepRite Wall & Wood Primer	ProClassic Alkyd Enamel	ProClassic Alkyd Enamel
Interior Doors/Trim - Painted	Acrylic	Clean & Dry	PrepRite Classic Primer	ProClassic WB Enamel	ProClassic WB Enamel
Interior Doors/Trim - Stained	Stain/Varnish	Clean, Dry & Sanded	Wood Classics Int Oil Stain	Wood Classics FD Varnish	Wood Classics FD Varnish
Exterior Siding/Trim	Alkyd/Acrylic	Clean & Dry	A-100 Ext Alkyd Primer	A-100 Exterior Satin	A-100 Exterior Satin
Exterior Siding/Trim	Acrylic	Clean & Dry	A-100 Ext Latex Primer	A-100 Exterior Satin	A-100 Exterior Satin

Always refer to product data page for additional information on surface preparation, application, environmental conditions, product uses and limitations.

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6.6.5 Resistance Properties of Various Coating Systems

Resistance Properties



This is a guide for selecting paint used in corrosive environments. Surface preparation S-W 14 (SSPC-SP2) Hand Tool Cleaning and S-W 15 (SSPC-SP3) Power Tool Cleaning are the minimums for steel in light service. When the coating will be subjected to severe exposure, the minimum surface preparation must be SW 17 (SSPC-SP6) Commercial Blast Cleaning.
If you know the generic type of system needed, refer to that generic group in the table and select the products listed that will best suit the environment the coating will be used in. If you are not certain of the coating to use, select the proper product by determining what type of exposure the coating will be subjected to. The recommendations of light, moderate, severe, and not recommended are used to describe resistance to chemicals and are defined as:

Light: if no failure occurs after a 6 hour exposure, the coating can be described as tolerating a light exposure to fumes other chemical listed.
Moderate: if no failure occurs after a 24 hour exposure, the coating can be described as resistant to moderate exposure, or exposure to occasional splash and spillage with the chemical being removed prior to evaporation and within 24 hours.
Severe: if no failure was indicated after 5 days or longer, the coating can be described as able to withstand severe exposure, defined as resistant to splash and spillage in areas where the material may evaporate in place.
Note: Resistance to fumes, splash, and spillage, not immersion
L - Light, M - Moderate, S - Severe, NR - Not Recommended

	aliphatic solvent	alkali	aromatic solvent	chlorinated solvent	fresh water	glycol ethers, alcohols	inorganic acids	oils	organic acids	oxygenated solvents
Acrylic										
Bond-Plex WB Acrylic Coating	S	L	L	L	S	L	M	S	L	NR
DTM Acrylic Coating	S	S	L	NR	S	S	S	S	NR	NR
Fast Clad HB Acrylic	S	M	M	L	M	L	M	S	S	NR
Metalatex Semi-Gloss	S	M	NR	L	M	L	L	S	L	NR
Sher-Cryl High Performance Acrylic	S	M	M	L	M	L	S	S	NR	L
SprayLastic Ext Semi-Gloss Dryfall	S	M	M	L	M	S	S	L	M	S
Alkyds										
Industrial Enamel HS	S	NR	NR	NR	S	L	L	S	L	NR
Industrial Urethane Alkyd	S	NR	NR	NR	S	L	L	S	L	NR
Metalastic DTM Enamel	S	NR	NR	NR	S	L	L	S	L	NR
Steel-Master 9500 Silicone Alkyd	S	NR	NR	NR	S	L	L	S	L	NR
Steel Spec Fast Dry Alkyd	S	NR	NR	NR	S	L	L	S	L	NR
Waterbased Industrial Enamel	L	NR	NR	NR	M	L	L	M	L	NR
Epoxies										
Dura-Plate 235	S	S	M	M	S	M	M	S	M	M
Hi Bild Waterbased Catalyzed Epoxy	S	S	M	M	S	M	M	S	M	M
Macropoxy 646 Fast Cure Epoxy	S	S	L	M	S	M	M	S	M	M
Macropoxy High Solids Epoxy	S	S	M	M	S	M	S	S	S	M
Tile-Clad High Solids Epoxy	S	S	M	M	S	M	M	S	M	M
Water Based Catalyzed Epoxy	S	M	NR	NR	S	M	S	S	M	NR
Waterbased Tile-Clad	S	S	M	M	S	M	M	S	S	M
Moisture Cured Polyurethanes										
ArmorSeal Rexthane I Floor Coating	S	S	S	M	S	S	S	S	S	S
Corothane I Aliphatic Finish Coat	S	M	M	L	S	M	M	S	M	M
Polyurethanes										
Acrolon 218 HS Acrylic Polyurethane	S	M	M	L	S	M	M	S	M	M
Centurion WB Urethane	S	M	S	M	S	M	S	S	M	S
Fast Clad DTM Urethane	S	M	S	M	S	M	M	S	M	M
Fast Clad Urethane	S	M	S	M	S	M	M	S	M	M
Hi-Solids Polyurethane	S	M	M	L	S	M	M	S	M	M
HydroGloss WB Urethane	S	M	S	M	S	M	S	S	M	S
Poly-Lon 1900 Polyester Polyurethane	S	M	S	M	S	M	M	S	M	M
Fluoropolymer Urethane										
FluoroKem Fluoropolymer Urethane	S	M	S	L	S	M	M	S	M	M

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6.6.6 Volatile Organic Compounds (VOCs) in Industrial Coatings

VOC — Volatile Organic Compound SHERWIN-WILLIAMS.

VOC's BY AREA	U.S. EPA	CARB	South Coast	OTC
Lacquers, Pigmented			275	
Low Solids Coatings**		120	120	120
Low Solids Stains**	120			
Low Solids Wood Preservatives**	120			
Magnesite Cement	600	450	450	450
Mastic Texture	300	300	300	300
Metallic Pigmented	500	500	500	500
Multi-Color	580	250	250	250
Nonferrous Ornamental Metal Lacquers & Surface Protectants	870			
Nonflat Coatings	380	150	50	150
Nonflat High Gloss Coatings		250	500	250
Non Flats, Interior	380			
Non Flats, Exterior	380			
Nuclear (Industrial Maintenance)	450			450
Pre-Treatment Wash Primers	780	420	420	420
Primers and Undercoaters	350			
Primers, Sealers, and Undercoaters		200	100	200
Quick Dry Enamels	450	250	50	250
Quick Dry Primers and Sealers				
Quick Dry Primers, Sealers, and Undercoaters	450	200	100	200
Recycled Coatings		250	250	250
Repair and Maintenance Thermoplastic	650			
Roof	250	250	50	250
Roof, Aluminum			100	
Rust Preventative	400	400	100	400
Sanding Sealers			275	
Sanding Sealers (Non-Lacquer)	550	350	275	350
Sealers (Including Clear Wood Sealers)	400			
Shellacs, Clear	730	730	730	730
Shellacs, Opaque	550	550	550	550
Shellacs, Pigmented				
Specialty Primers			250	
Specialty Primers, Sealers, and Undercoaters		350		350
Stains		250	100	250
Stains, Clear	550			
Stains, Interior			250	
Stains, Semitransparent Interior	550			
Stains, Opaque	350			
Stain Controllers	720			
Swimming Pool	600	340	340	340
Swimming Pool Repair & Maintenance		340	340	340
Temperature-Indicator Safety		550		550
Thermoplastic Rubber and Mastics	550			550
Traffic Marking	150	150	100	150
Traffic, Applied to Other Surfaces				
Traffic, Applied to Public Streets and Highways				
Traffic, Black Traffic Coatings				
Varnishes	450	350	275	350
Waterproof Mastics				
Waterproofing Sealers		250	100	250
Waterproofing Sealers, Concrete/Masonry		400	100	400
Water Proofing Sealers and Treatments, Clear	600			
Water Proofing Sealers and Treatments, Opaque	600			
Wood Preservatives		350	350	350
Wood Preservatives, Below Ground	550		350	
Wood Preservatives, Clear and Semitransparent	550			
Wood Preservatives, Opaque	350			
Zinc Rich Industrial Maintenance Primers			100	
Zone Marking	450			

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6.7.0 Vinyl Wall Coverings

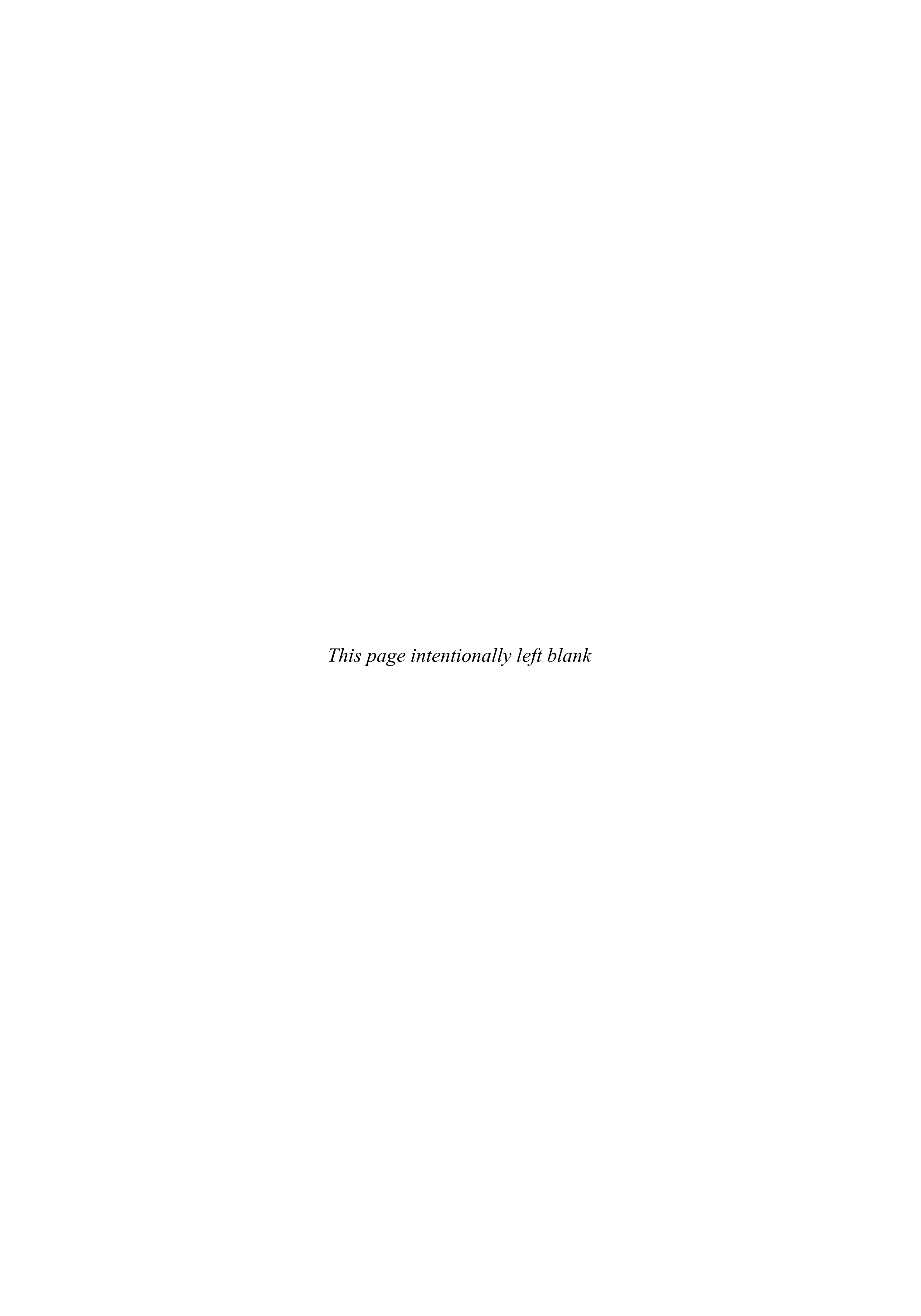
Federal Specification CCC-W-408 lists three types of vinyl wall covering: light duty, medium duty, and heavy duty. Note the flame spread rate for types I and II.

Three Types and Two Classes of Vinyl Wall Covering:nyl Wall Covering:			
Type 1	Light Duty	7 oz. per sq. yard	For use as a maintenance-free covering for areas not subjected to abrasion or wear traffic, and for ceilings.
Type 2	Medium Duty	13 oz. per sq. yard	For general use in area where there is average traffic and scuffing.
Type 3	Heavy Duty	22 oz. per sq. yard	For use only as wainscoting or lower wall protection for areas exposed to damage by moveable equipment or to abusive conditions, such as exist in hospitals.
Class 1	Regular Finish		
Class 2	Mildew-Resistant Finish		

	Type I Results		Type II Results		
Ounce Weight:	12/13oz.	15/16oz.	18/19oz.	20/21oz.	24oz.
Flame Spread	5	10	5	10	10
Smoke Developed	0	0	0	0	20

6.7.1 Availability of Wall Coverings of Various Types

Description	Width (in.)	Trimmed Width (in.)	Length per Role (yd)
Burlap-paper backed	36	same	4
Canvas-prefinished	24, 27, 48	same	5
Cork laminated to cloth backing	50	48	35
Fabric-paper backed	36, 40	same	3, 4
Felt-paper backed	54	53	Sold per lineal yard
Grass cloth	30, 36	34–35	4, 5
American paper	20, 27, 30, 36, 41, 48	18, 25, 28, 34, 39, 46	3, 5, 7
English	22	21	11
Flocked	Varies from 29 according to pattern	Varies from 27 according to pattern	5
Foil	30	Pretrimmed	5
French	19, 21	17, 19	7



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Section

7

Doors and Windows

Contents

7.0.0 Hollow Metal Frame and Door Selection Guide for Various Building Types

Note: Refer to Section 7.0.2 for door construction level and to Section 7.1.0 for door design nomenclature.

Apartment Buildings

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X			X		X	
Unit Entrance	X	X			X				
Stairwell		X	X				X		
Bathroom	X				X				
Bedroom	X				X				
Interior Rooms	X				X				
Closet	X				X				
Storage					X				
Laundry / Utility	X				X	X	X		X
Garage / Parking					X		X		X

Hotels / Motels

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance		X	X		X		X	X	X
Unit Entrance	X	X			X		X		
Secondary Entrance / Exit			X	X	X		X		
Stairwell		X	X				X		
Fire Exit		X	X		X		X		X
Smoke Barrier (Double Egress)		X			X		X		
Bath	X				X		X		
Connecting Rooms	X				X		X		
Closet	X				X		X		
Kitchen		X	X		X	X	X		
Office	X				X	X	X		
Storage / Utility		X	X	X	X		X		
Laundry		X	X		X		X		
Pool Area / Equipment		X			X		X		

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7.0.0 Hollow Metal Frame and Door Selection Guide for Various Building Types (Continued)

Health Care Facilities

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X			X		X	X
Service Entrance			X	X	X		X		
Stairwell		X	X				X		
Corridor		X	X		X	X	X		X
Bedroom	X				X				
Patient Room		X			X				
Operating & Exam Rooms		X	X		X				
Pharmacy			X	X	X		X		
Recreation / Lounges		X			X		X		
Closet	X				X				
Kitchen		X	X				X		

Office Buildings

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X			X		X	X
Service / Supply Entrance			X	X	X				
Stairwell		X	X				X		
Restroom		X	X						
Individual Office	X				X				
Closet	X				X				
Equipment Room		X	X			X			
Boiler Room		X	X		X				

Industrial / Offices

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X			X		X	
Secondary Entrance			X	X	X		X		
Stairwell		X	X				X		
Restroom		X	X		X				
Individual Office	X				X				
Closet	X				X				

Industrial Manufacturing

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X					X	X
Secondary Entrance			X	X	X				
Restroom			X		X				
Cafeteria			X			X			
Equipment Room	X	X			X				
Boiler Room			X		X				
Parts Crib		X			X				
Tool Room					X	X			

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7.0.0 Hollow Metal Frame and Door Selection Guide for Various Building Types (Continued)

Dormitories

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X	X				X	X
Unit Entrance	X	X			X				
Stairwell		X	X				X		X
Bathroom	X				X				
Bedroom	X				X				
Closet	X				X				

Schools

Usage	Door Construction Level				Door Design Nomenclature				
	1	2	3	4	F	G	V	FG	N
Main Entrance			X			X		X	X
Secondary Entrance / Exit			X	X	X		X		
Stairwell		X	X				X		X
Restroom		X			X				
Classroom		X							X
Locker Room		X	X						
Closet	X				X				
Cafeteria / Kitchen	X	X				X			X
Storage / Utility		X			X				
Boiler Room		X	X		X				

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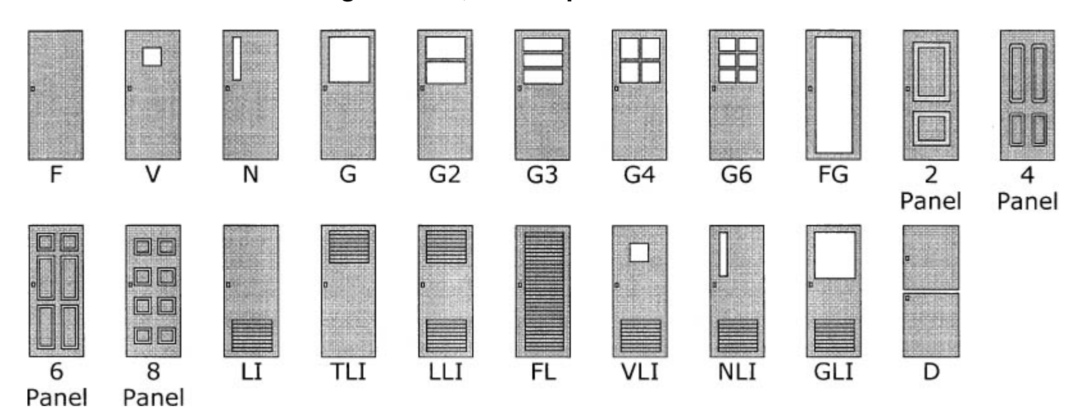
7.0.1 Hollow Metal Doors and Frames—Levels 1 to 4

Selection and Usage Guide

Door Style	Recommended Door Usage	Recommended Gage of Frame
Level 1 - Standard Duty		
Model 1 - Full Flush	DM / DL 420, DE 820 / 18 (Honeycomb, styrene, or urethane core)	16 / 18 gage - 1.3mm / 1mm
Model 2 - Seamless	DM / DL 420, DE 820 / 18 (Honeycomb, styrene, or urethane core)	16 / 18 gage - 1.3mm / 1mm
Level 2 - Heavy Duty		
Model 1 - Full Flush	DM / DL / DE 418 (Honeycomb, styrene, or urethane core) Embossed 2, 6, & 8 panels	16 gage - 1.3mm
Model 2 - Seamless	DM / DL / DE 418 (Honeycomb, styrene, or urethane core) Embossed 2, 6, & 8 panels	16 gage - 1.3mm
Level 3 - Extra-Heavy Duty		
Model 1 - Full Flush	DL / DE 416 (Honeycomb, styrene or urethane core)	14 / 16 gage - 1.7mm / 1.3mm
Model 2 - Seamless	DL / DE 416 (Honeycomb, styrene or urethane core)	14 / 16 gage - 1.7mm / 1.3mm
Level 4 - Maximum Duty		
Model 1 - Flush	DE 414 (Honeycomb, styrene or urethane core)	14 / 16 gage - 1.7mm / 1.3mm
Model 2 - Seamless	DE 414 (Honeycomb, styrene or urethane core)	14 / 16 gage - 1.7mm / 1.3mm

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7.1.0 Basic Hollow Metal Door Configurations, Core Options



Optional Door Cores

- Polystyrene (Solid Core) - 1 lb density expanded polystyrene per ASTM 578 U-Factor of .13
- Polyurethane (Solid Core) - 2 lf density polyurethane per ASTM C591 U-Factor of .10
- Steel Stiffened - Vertical hat shaped stiffeners of 20, 18, and 16 gauge with mineral wool or fiberglass batting between stiffeners. Stiffeners are welded maximum of 6" apart and on 5" centers.
- Temperature Rise/Mineral Fiberboard - Mineral fiberboard capable of withstanding a maximum of 250° temperature rise in 30 minutes. U-Factor of .26

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7.1.1 Basic Hollow Metal Frames—Drywall Installation

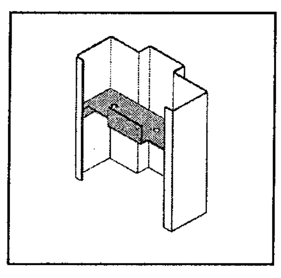
Drywall (MH Series) Frames

Stud		Thickness		Frame Depth (Size of Frame to Specify)
Size	Type	Drywall	Wall	
1 Layer of gypsum board each side of the wall				
1 5/8" (41 mm)	Steel	½" (13 mm)	2 5/8" (67 mm)	3 5/8" (91 mm)
1 5/8" (41 mm)	Steel	5/8" (16 mm)	2 7/8" (73 mm)	3 7/8" (96 mm)
2½" (63 mm)	Wood or Steel	½" (13 mm)	3½" (89 mm)	4½" (114 mm)
2½" (63 mm)	Wood or Steel	5/8" (16 mm)	3¾" (95 mm)	4¾" (121 mm)
2½" (63 mm)	Wood or Steel	¾" (19 mm)	4" (102 mm)	5" (127 mm)
3½" (88 mm)	Wood	½" (13 mm)	4½" (114 mm)	5½" (140 mm)
3½" (88 mm)	Wood	5/8" (16 mm)	4¾" (121 mm)	5¾" (146 mm)
3 5/8" (88 mm)	Steel	5/8" (16 mm)	4 7/8" (124 mm)	5 7/8" (149 mm)
1 Layer of gypsum board one side of the wall and 2 on the other side of the wall				
2½" (63 mm)	Wood or Steel	½" (13 mm)	4" (102 mm)	5" (127 mm)
3½" (88 mm)	Wood	½" (13 mm)	5" (127 mm)	6" (152 mm)
2 Layers of gypsum board each side of the wall				
2½" (63 mm)	Wood or Steel	5/8" (16 mm)	5" (127 mm)	6" (152 mm)
3 5/8" (91 mm)	Steel	5/8" (16 mm)	6 1/8" (156 mm)	7 1/8" (181 mm)
3 Layers of gypsum board each side of the wall				
1 5/8" (41mm)	Steel	½" (13 mm)	4 5/8" (117 mm)	5 5/8" (143 mm)

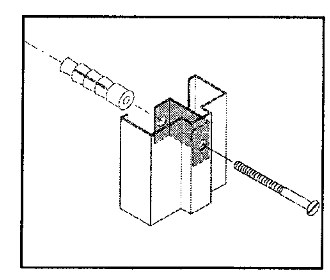
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7.1.2 Drywall Frame Anchor Details

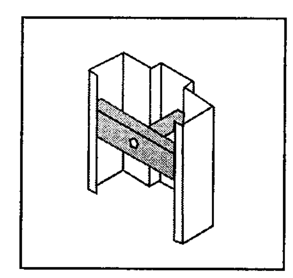
ME SERIES - ANCHOR DETAILS



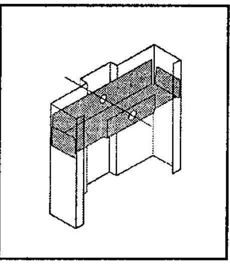
Steel Stud Anchor



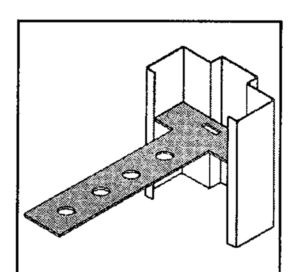
Prepared Opening Anchor



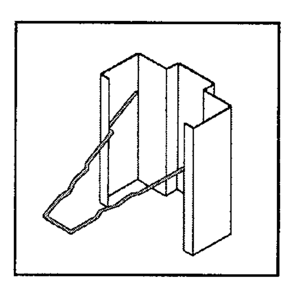
Twist in Prepared Opening Anchor



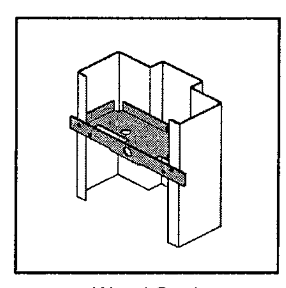
Snap-in Prepared Opening Anchor



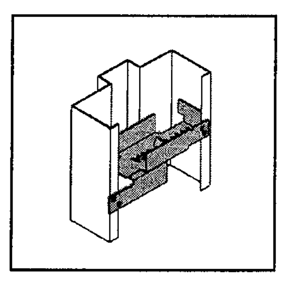
Tee Masonry Anchor



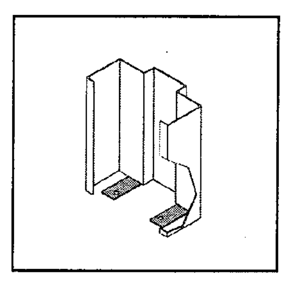
Wire Masonry Anchor



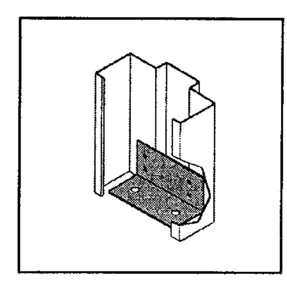
Wood Stud Anchor



Adjustable Wood/Steel Stud Anchor (Assembled)



Integral Sill Anchor (5-3/4 Stock Only)

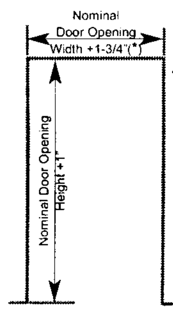


One Piece Sill Anchor Welded On

By permission, Republic Doors and Frames, McKenzie, TN.

7.1.3 Installation Techniques—Knocked-Down (KD) Drywall Frames

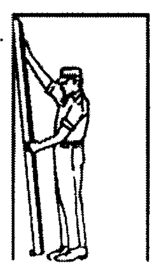
INSTALLATION OF (MH) DRYWALL FRAMES



1. Provide for rough opening as shown.

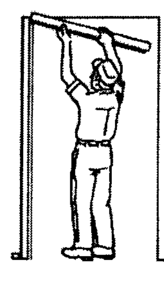
 *Nominal Door opening width + 1-3/4"
 Nominal Door opening height + 1"
 (Assuming 2" face dimension)

 Nominal Door opening width + 3" - For single rabbeted or cased opening frames.

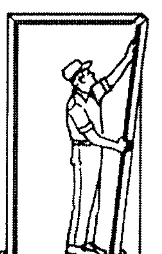


2. Drive sill anchors on to bottom of both jambs.

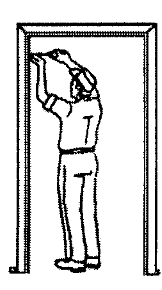
 Slip hinge jamb over wall into position.



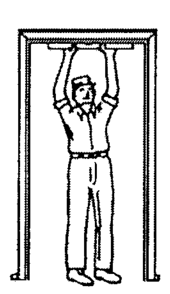
3. Slip header over wall and engage header aligning tab in slot of hinge jamb.



4. Slip strike jamb over wall and engage header aligning tab in slot of strike jamb.

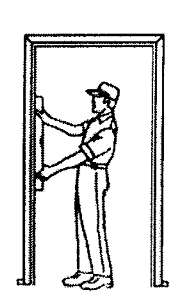


5. Position adjustable pressure anchor by turning adjusting screw clockwise an equal amount for both anchors. After contact is made with studs, continue tightening until frame is wedged between studs. (Do not over-tighten.)



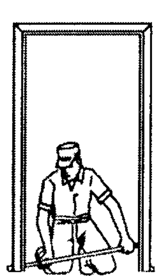
6. Level header.

 Shim jambs at base if required.



7. Plumb hinge jamb.

 Fasten hinge jamb sill anchors securely with nails or screws.



8. Size opening by inserting wood spreader cut to exact opening width and fasten sill anchor at strike jamb with nails or screws.

 Remove spreader. Insert adjusting screw cover.

 Attach (2) #8 x 1/2 STS to each corner for labeled single frames over 7'-2" in height and all double frames.

 Frame is now ready for door and hardware.

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7.1.4 Hollow Metal Frame Profiles and Types of Wall Construction

Flush Frame Selections

The following charts show recommended Republic frames for a variety of wall constructions. Locate the wall requirements on the charts below, then find the frame most suitable for the specified usage.

Notes:

- Size of frame to specify will vary with stud size
- Frames can also be used in wall conditions other than those shown below
- Frames for these walls can be KD (knock-down) or SUA (welded)

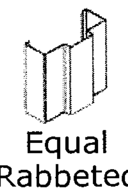
Flush (ME Series) Frames

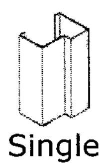
Wall Detail and Type	Frame Depth (size of Frame to Specify)				
Wrap around concrete block	**4¾**	**5¾**	**6¾**	**7¾**	**8¾**
4" (100 mm) masonry unit	X				
6" (150 mm) masonry unit			X		
8" (200 mm) masonry unit					X
Butted Masonry	**4¾**	**5¾**	**6¾**	**7¾**	**8¾**
6" (150 mm) masonry unit	X	X			
8" (200 mm) masonry unit	X	X	X	X	
Cavity wall, 4" (100 mm) masonry units			X	X	X
Cavity wall, 6" (150 mm) masonry units					X

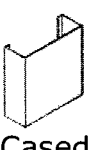
By permission, Republic Doors and Frames, McKenzie, TN.

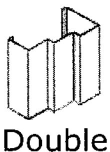
7.1.5 Hollow Metal Frame Profiles and Typical Wall Construction

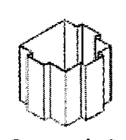
Additional ME Frame Types Available

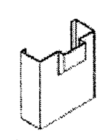

Equal Rabbeted


Single Rabbet

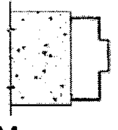

Cased Open

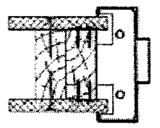

Double Egress

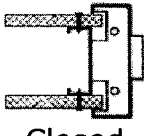

2 and 3 Way Corner Posts

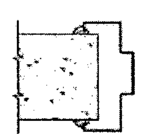

Hospital Stops

Typical Wall Construction


Masonry Butted

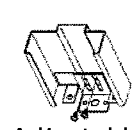
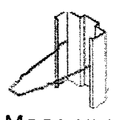
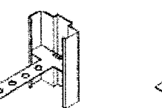
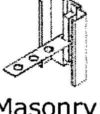
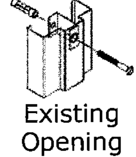

Closed Wood Stud


Closed Steel Stud


Wrap around masonry (Block or pre-poured)

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7.1.6 Various Anchor Details for Masonry Frame Installations Construction

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7.1.7 Hollow Metal Frame for CMU, Tile, Wood and Steel Studs

Concrete block and tile	**4¾**	**5¾**	**6¾**	**7¾**	**8¾**
Cavity wall, 4" (100 mm) masonry units	X				
4" (100 mm) masonry unit, brick veneer, plaster inside		X			
4" (100 mm) masonry unit, brick veneer			X		
Cavity wall, 4" (100 mm) masonry unit, brick veneer				X	
Existing wall	**4¾**	**5¾**	**6¾**	**7¾**	**8¾**
Poured concrete or concrete block	X	X	X	X	X
Wood / Steel stud walls	**4¾**	**5¾**	**6¾**	**7¾**	**8¾**
2" x 3" (50 mm x 75 mm) wood stud, ½" wall board each side	X				
Closed steel stud, gypsum	X	X	X	X	
2" x 4" (50 mm x 100 mm) wood stud, gypsum		X			
2" x 4" (50 mm x 100 mm) wood stud, gypsum, brick veneer			X	X	
2" x 6" (50 mm x 150 mm) wood stud, 5/8" (16 mm) gypsum				X	
2" x 6" (50 mm x 150 mm) wood stud, ½" (13 mm) & 5/8" (16 mm) gypsum 2 side				X	

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7.1.8 Basic Hollow Metal Fire Door Requirements

BASIC FIRE DOOR REQUIREMENTS

Fire door openings are classified by their locations in the building. The location determines the length of exposure protection required, based on the potential fire hazard of that particular area. The six opening classifications are shown below along with the six door ratings and the maximum amount of glass in square inches allowed for each door.

Label Classification	Location In Building	Maximum Glass Area
3 HOUR RATING	3 hour rated opening (Class A). Openings are in walls separating buildings or dividing a single building into fire areas. Doors for these openings require a fire protection rating of 3 hours.	100 square inches per leaf. See note 1.
1-1/2 HOUR RATING	1 1/2 hour rated opening (Class B). Openings are in enclosures of vertical communication through buildings. These could be stairwells or elevator shafts. While not a means of vertical communication, boiler room doors are generally categorized as Class "B" openings. Door for these areas require a fire protection rating of 1 1/2 hours, and glass areas may not exceed 100 square inches per individual door leaf except as noted below.	100 square inches per leaf. See note 2.
3/4 HOUR RATING	3/4 hour rated opening (Class C). Openings are in corridors and room partitions. Doors for these areas require a fire protection rating of 3/4 hour, and the glass area cannot exceed 1296 square inches per light with no dimension exceeding 54 inches except as noted below.	1296 square inches per light. Neither dimension to exceed 54". See note 2.
1-1/2 HOUR RATING	1 1/2 hour rated opening (Class D). Openings are in exterior walls which are subject to severe fire exposure from the outside of the building. Doors for these areas require a fire protection rating of 1 1/2 hours.	See note 3.
3/4 HOUR RATING	3/4 hour rated opening (Class E). Openings are in exterior walls which are subject to moderate or light fire exposure from the outside of the building. A typical example would be a door leading to an exterior fire escape. Doors for these openings require a fire protection rating of 3/4 hour with glass areas not exceeding 1296 square inches per light with no dimension exceeding 54 inches.	1296 square inches per light. Neither dimension to exceed 54". See note 3.
20 MINUTE	20 minute fire rated door frame assemblies are normally found in interior partitions and are intended for installation with 20 minutes fire rated doors of the single swing, swing in pairs, or double egress types.	1296 square inches per light. Neither dimension to exceed 54". See note 2.

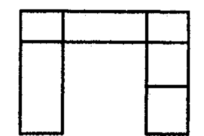
Note 1. 100 square inches when using Firelite glass. Neither dimension exceeding 33".
Note 2. Except when using Pemko fire glazing compound. See U.L. procedure or consult factory.
Note 3. Consult with local authority having jurisdiction for allowable glass.

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7.1.9 Labeled Hollow Metal Frame Size and Types

LABELED FRAME SIZES AND TYPES

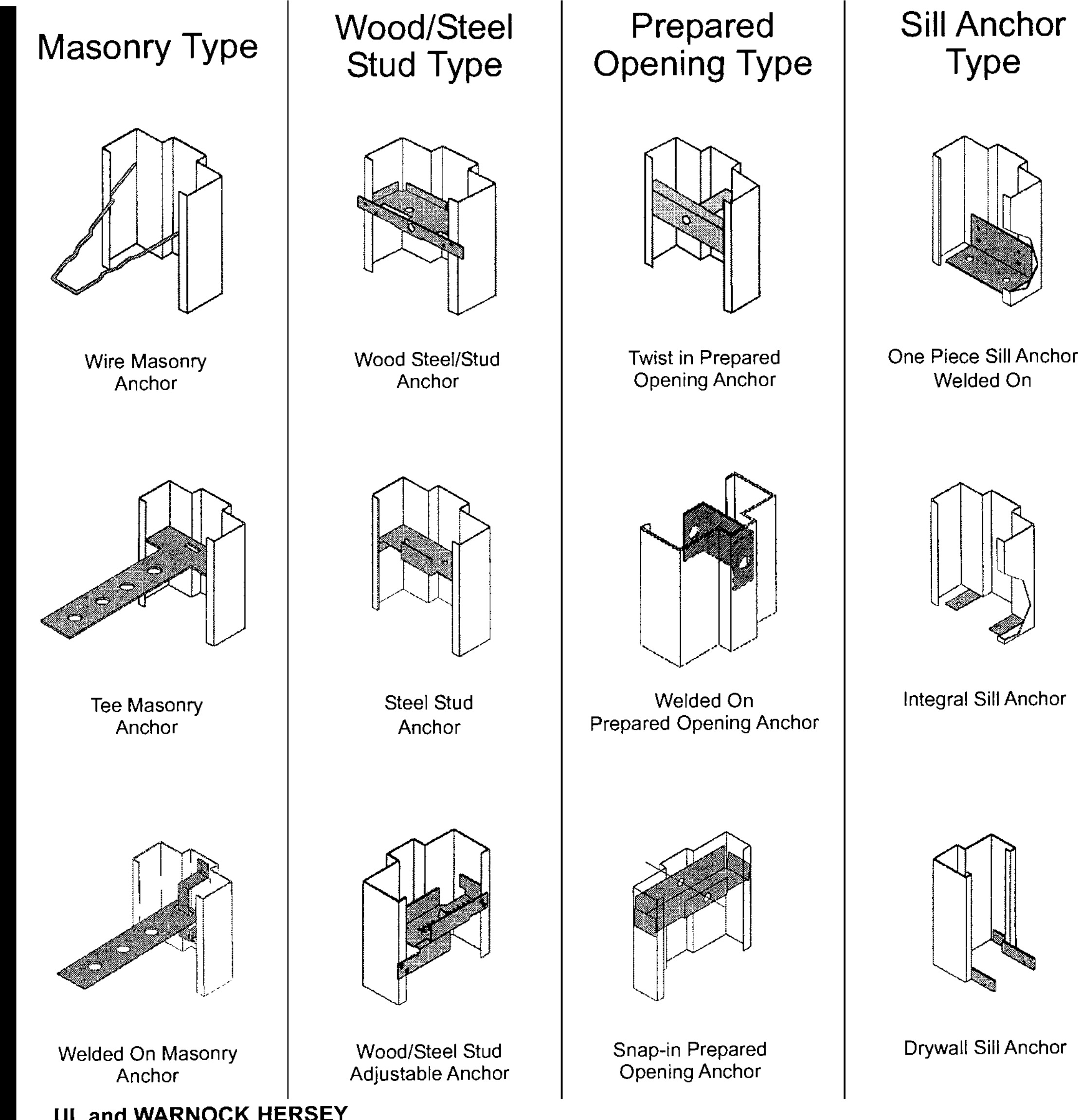
One Hour Transom Sidelite Frames
With Firelite or Firelite Plus Glass



- Maximum door size 8080.
- ME/SE series profile may be 16 gage or 14 gage steel.
- MH/SH series profile may be 16 gage steel.
- Jamb depth ME/SE profile single rabbet 3" to 20", double rabbet 5 3/4" to 20".
- Jamb depth MH/SH profile single rabbet 3 1/2" to 15", double rabbet 4 1/2" to 15".
- The overall frame size shall not exceed 122" (10'2") in width and 121" (10'1") in height.
- The maximum size opening for the individual transom lights or sidelights shall not exceed 2721 sq. in. and the maximum width and height of the individual lights shall not exceed 54" and 77 3/4" respectively.
- 5/8" high glazing bead.
- Welded construction only.
- Only labeled sealant or 100% silicone sealant may be used as a glazing compound for installing Firelite.
- All types of anchors are approved. Masonry anchors may be loose or welded. Drywall anchors must be welded. All frames exceeding 8' x 9' must have anchors welded in place.
- Also available for borrowed light frames.
- Face Dimensions: Refer to U.L. or W.H. procedure manual or contact factory.

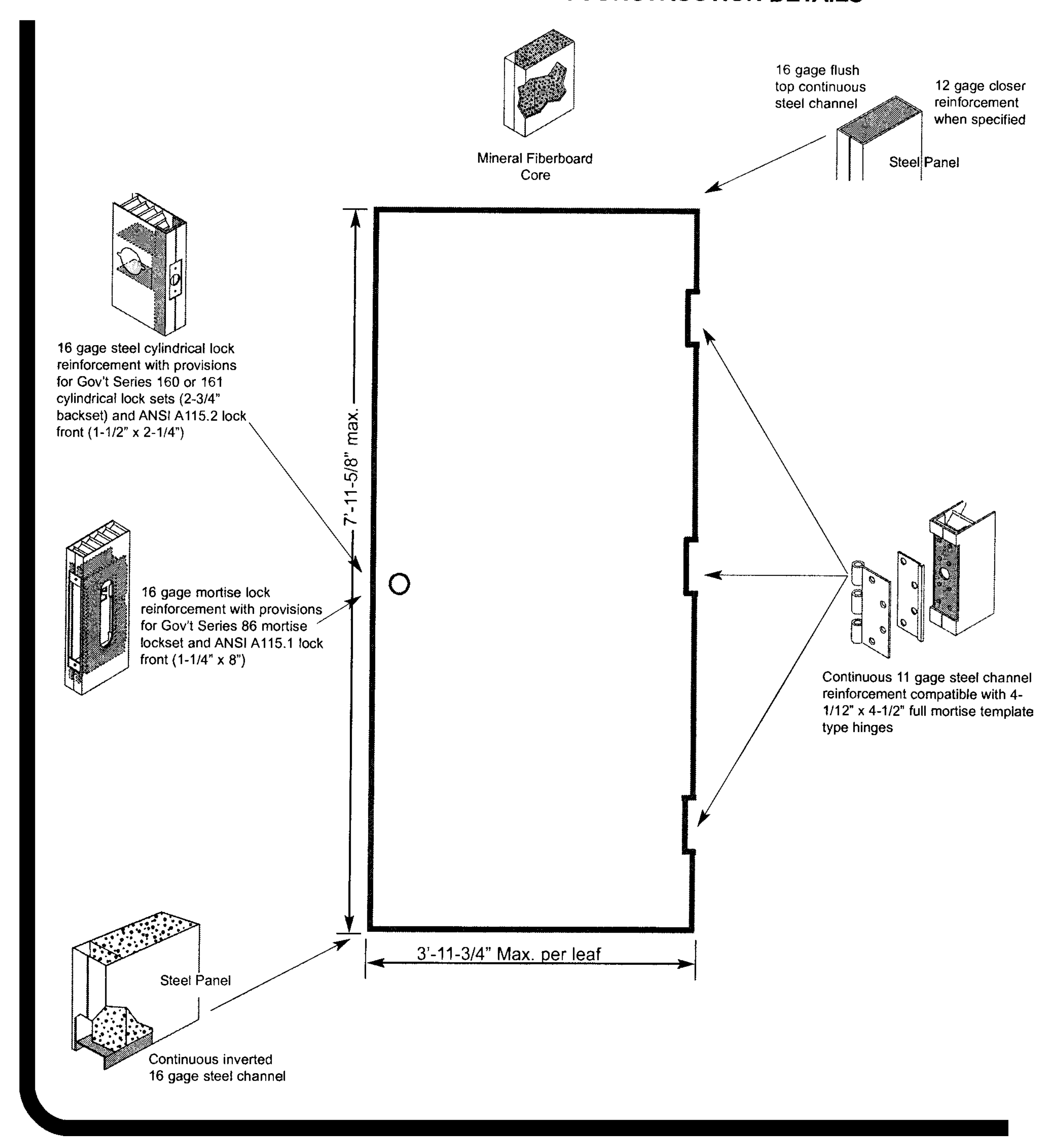
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7.1.10 Labeled Hollow Metal Frame Anchor Details



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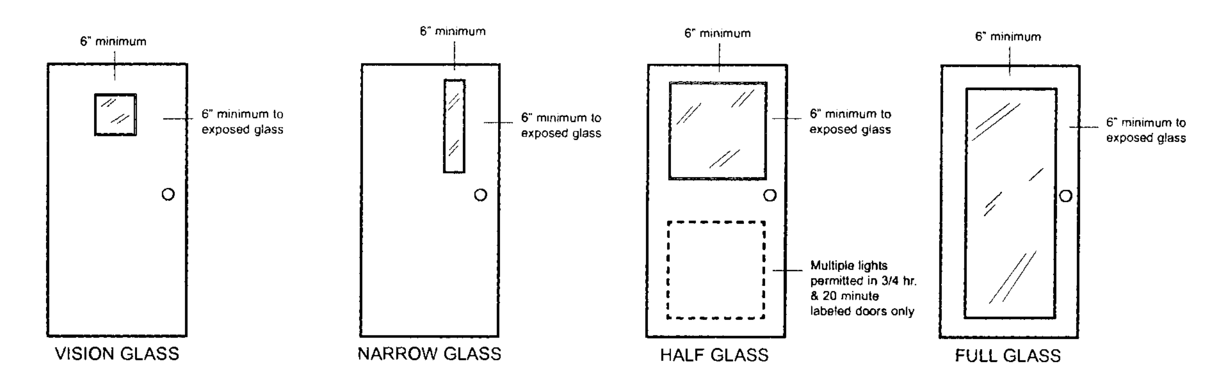
7.1.11 U.L.-Labeled HM Fire Door Construction Details



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7.1.12 Hollow Metal Fire-Rated Doors with Glass

FIRE DOORS WITH GLASS



DOOR TYPE	MAXIMUM SIZE	VISION GLASS	NARROW GLASS	HALF GLASS	FULL GLASS
DE 820	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DE 818	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DM 820	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DL/DE 420	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DL/DE 418	40100	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DL/DE 416	40100	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DL/DE 420 (Insulated)	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	Not Available
DL/DE 418 (Insulated)	4080	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	Not Available
DL/DE 416 (Insulated)	4080	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	Not Available
DL/DE 420 (Temp. Rise)	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	Not Available	Not Available
DL/DE 418 (Temp. Rise)	4080	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	Not Available	Not Available
DL/DS 418	40100	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	Not Available
DL/DS 416	40100	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	Not Available
DM 420	3072	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
DM 418	4070	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream
UNIFIT™	4080	3 Hr., 1-1/2 Hr., 3/4 Hr., 20 Min.	3, 1-1/2 Hr., 3/4 Hr., 20 Min.	3/4 Hr., 20 Min.	20 Min Without Hose Stream

- Vision Glass - exposed glass area is not to exceed 100 square inches with no dimension exceeding 33".
- 3-hour doors with light must incorporate Firelight or Firelight Plus glazing.
- Narrow Glass - exposed glass area is not to exceed 100 square inch with no dimension exceeding 33".
- Half Glass - exposed glass area is not to exceed 1296 square inch with no dimension exceeding 54".
- Full Glass - exposed glass area is not to exceed 2994 square inch with the width not to exceed 35-13/16" and the height not to exceed 85-5/8".
- Doors may be provided for Listed glass kits to be installed at the job site. A supplemental marking is required specifying which manufacturer's glass kit is to be used. Reinforcing channels must be provided unless All Metal Stamping Model No. 110UL kit or Anemostat Listed kit with HM clips is used.
- Other approved glass kits for use in RBP doors are manufactured by Leslie-Locke and Air Louver.
- See Technical Data Sheet 405 for Unifit™ door limitations.

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7.1.13 U.L.-Labeled HM Borrowed Light and Transom Frames

LABELED FRAME SIZES AND TYPES

Borrowed Light Frame

Typical Elevation

- Labeled frames may be of 16 gage or 14 gage steel.
- Maximum size: 9'4" (2845) wide x 8'10" (2692) high.
- Jamb Depth: 4 3/4" (121) to 20" (508).
- Face Dimensions: 1" (25) minimum - 2" (51) maximum.
- Maximum Rating: 3/4 hour.
- Maximum Exposed Glass: 2650 sq. in. with a maximum exposed width of 53" (1346) and maximum expanded height of 50" (1270).
- A stop height of 5/8"(16) is required for a maximum exposed glass of up to 2650 sq. in.
- Fire window frames are intended for installation in masonry walls or for installation in walls utilizing wood/steel studs.
- Each jamb shall be provided with a sill anchor and a jamb anchor for each 30" (762) of height or fraction thereof. An intermediate base anchor is required for frames over 4'0" (1219) wide.
- Must be welded (3/4 hour).

20 Minute Frame with Lights

- Twenty minute type door frame with lights, fire tested without hose stream, for walls at least 3 1/2" (89) thick.
- ME/SE Series profile may be 12 gage, 14 gage or 16 gage steel.
- MH/SH Series profile may be 16 gage steel.
- Mitered corner connections are standard. 12 gage will be coped.
- Jamb Depth:
  ME/SE profile - Sgl. Rbt. 3" (76) to 20" (508).
  Dbl. Rbt. 4 1/2" (114) to 20" (508).
  MH/SH profile -Sgl. Rbt. 3 1/2" (89) to 15" (381).
  Dbl. Rbt. 4 1/2" (114) to 15" (381).
- The overall frame size shall not exceed 158 in. (4013) (13ft. 2 in.) in width and 139 in. (3531) (11 ft. 7 in.) in height.
- The maximum size opening for the individual transom lights or sidelights shall not exceed 5268 inches in area, and the maximum width or height of the individual light shall not exceed 109 3/4 inches (2788).
- 5/8" (16) glazing bead.
- Also available for borrowed lights.

Transom Frames

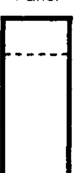
Transom Frame Without Transom Bar

Wood Panel

- Labeled frames may be of 16 gage, 14 gage or 12 gage steel.
- Maximum frame opening size: 4'0" (1219) x 11'0" (3353).
- Maximum door size: 4080.
- Maximum panel height: 48 1/2" (1232)-
- Jamb Depth: 4 1/2" (114) thru 20" (508).
- Maximum rating: 1 1/2 hour.
- Requires a supplemental marking that specifies:
  "FOR USE ONLY WITH A CLASSIFIED TRANSOM PANEL AND ANY CLASSIFIED FIRE DOOR HAVING A RATING UP TO 1 1/2 HOURS."

Transom Frame With Transom Bar

Hollow Metal Panel



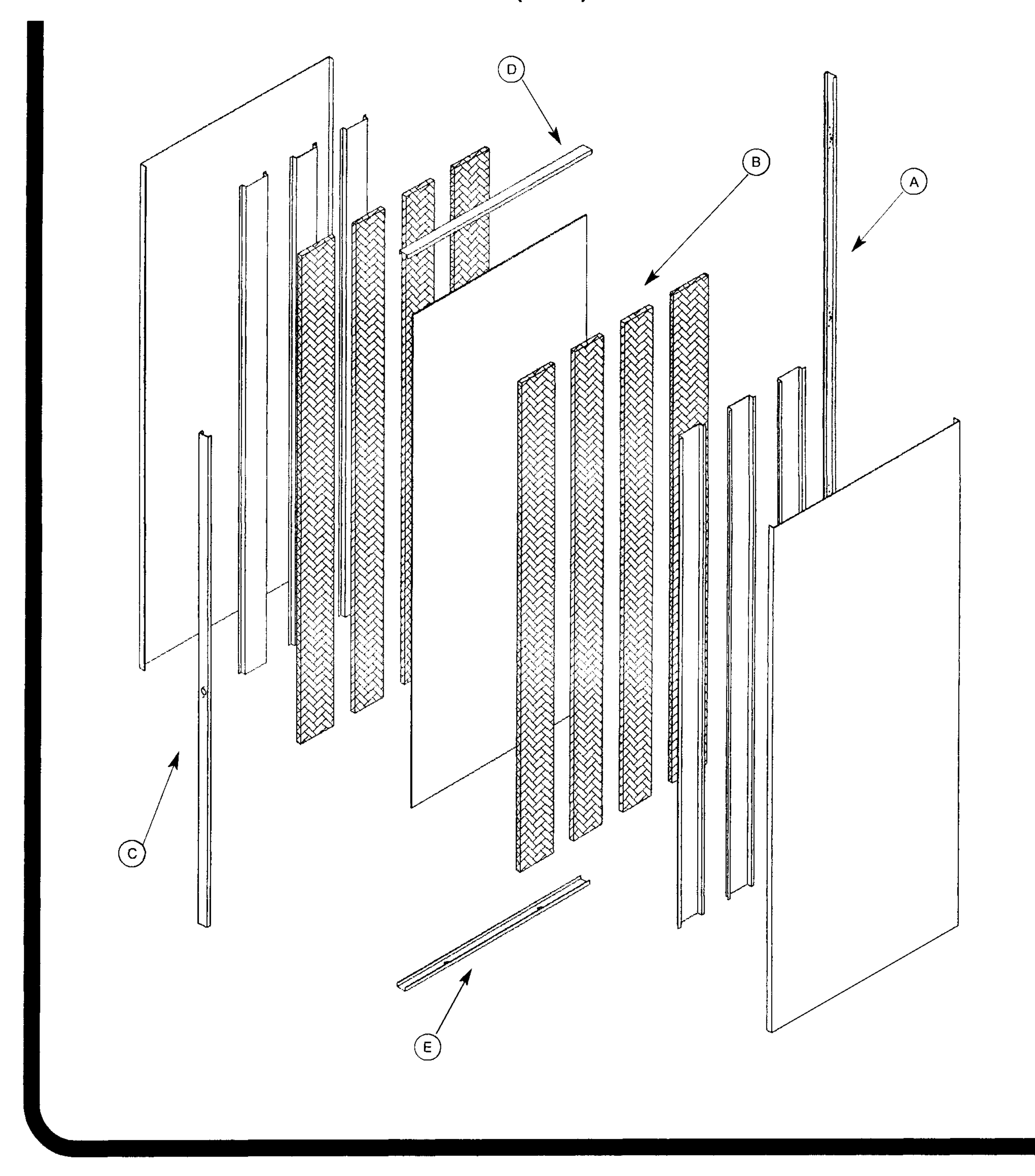
- Labeled frames may be of 16 gage, 14 gage or 12 gage steel.
- Maximum frame opening size: 4'0" (1219) x 11'0" (3353).
- Maximum door size: 4080.
- Maximum panel height: 4'0" (1219).
- Jamb Depth: 4 1/2" (114) thru 20" (508).
- Maximum rating: 3 hours.
- Maximum panel height: 34" (864)

Transom Frame Without Transom Bar

Hollow Metal Panel

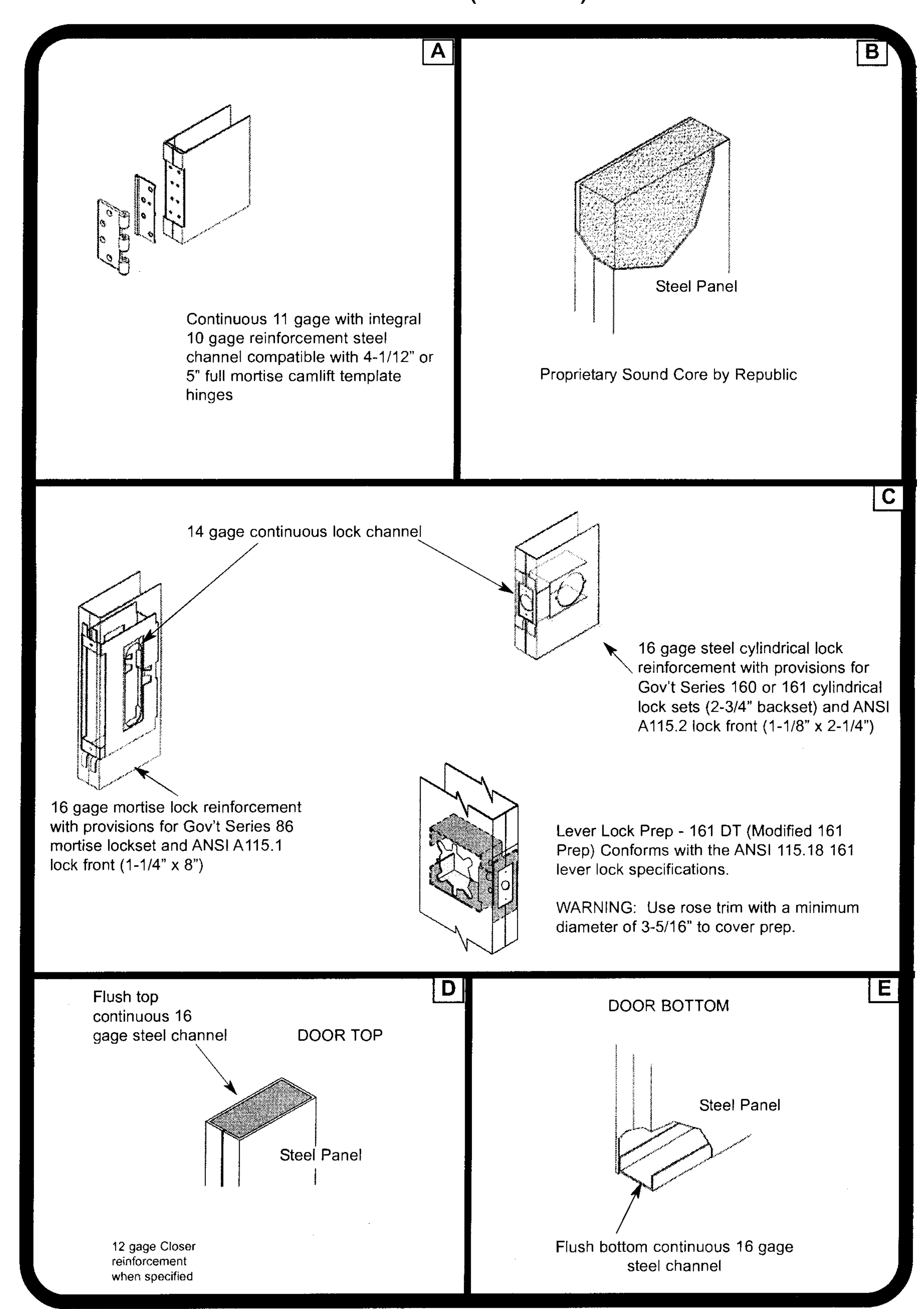
- Labeled frames may be of 16 gage, 14 gage or 12 gage steel.
- Labeled panels may be of 18 or 20 ga. steel.
- Maximum frame opening size: 4'0" (1219) x 11'0" (3353).
- Maximum door size: 4080 single.
- Jamb Depth: 4 1/2" (114) thru 20" (508).
- Maximum rating: 3 hours.
- Astragal required at bottom of panel for 3 hour rating.
- Maximum panel height: 34" (864).

7.1.14 Sound Transmission–Rated Hollow Metal Doors



By permission, Republic Doors and Frame, McKenzie, TN.

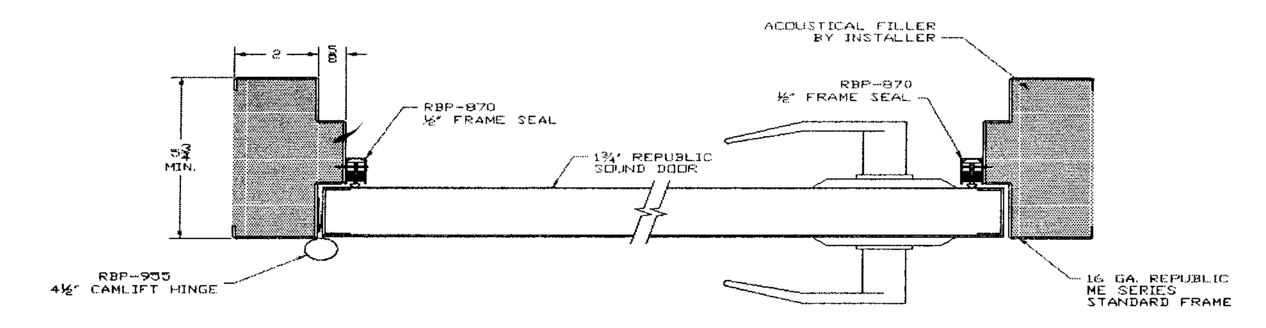
7.1.14 Sound Transmission–Rated Hollow Metal Doors (Continued)

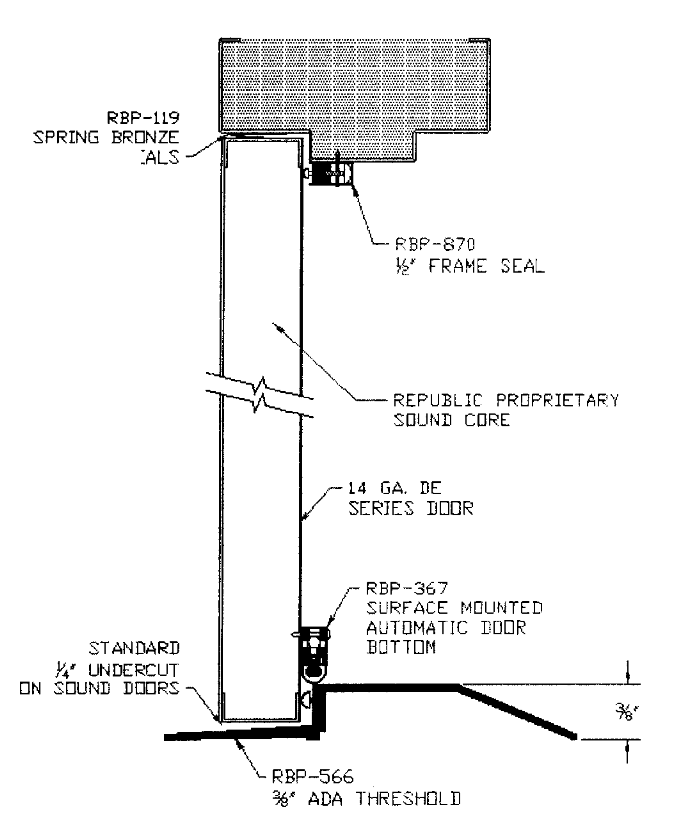


By permission, Republic Doors and Frame, McKenzie, TN.

7.1.14.1 Typical Head and Sill Details for STC 48 and 50 Systems

Typical Republic STC 48 & 50 Systems





Typical Head & Sill Detail

Installation Instructions For Acoustic Gaskets

Republic STC system includes: R-566 threshold, R-870 adjustable head and jamb seals, R-119 spring bronze head and jamb seals, R-367 surface mounted automatic door bottom and R-955 Cam-Lift hinges.

1. Door should be hung on RBP-955 hinges accordingly. The RBP-119 spring bronze should be installed on the bottom of the door before hanging.

2. Install the RBP-566 threshold to suit floor condition. Caulk round the bottom of threshold along with the entire perimeter of frame and at meeting edges of threshold and frame.

3. Close the door and measure the frame opening width and height. Install the RBP-870 head piece first (trim as necessary). Place the piece against the face of the door, making **gentle** contact between the "rubber extrusion" seal and the door, then fasten in place. Place the hinge side seal against the face of the door, making **gentle** contact between the "rubber extrusion" seal and the door, then fasten in place. Place the strike side seal against the face of the door, making **gentle** contact between the rubber extrusion seal and the door, then fasten in place.

4. Install the RBP-119, head piece first, then the hinge side and finally the lock side using the pressure sensitive tape to fasten the spring bronze to the frame.

5. Install the RBP-637 automatic door bottom last (Required only on STC-50) cut the automatic door bottom to fit between the RBP-870 gasketing previously installed on the jambs, (see bottoms). Fasten the door bottom so that there will be a space of 3/8" between the top of the threshold and the bottom of the automatic door bottom. Adjust the door bottom as required by turning the adjustment screw for the prober seal.

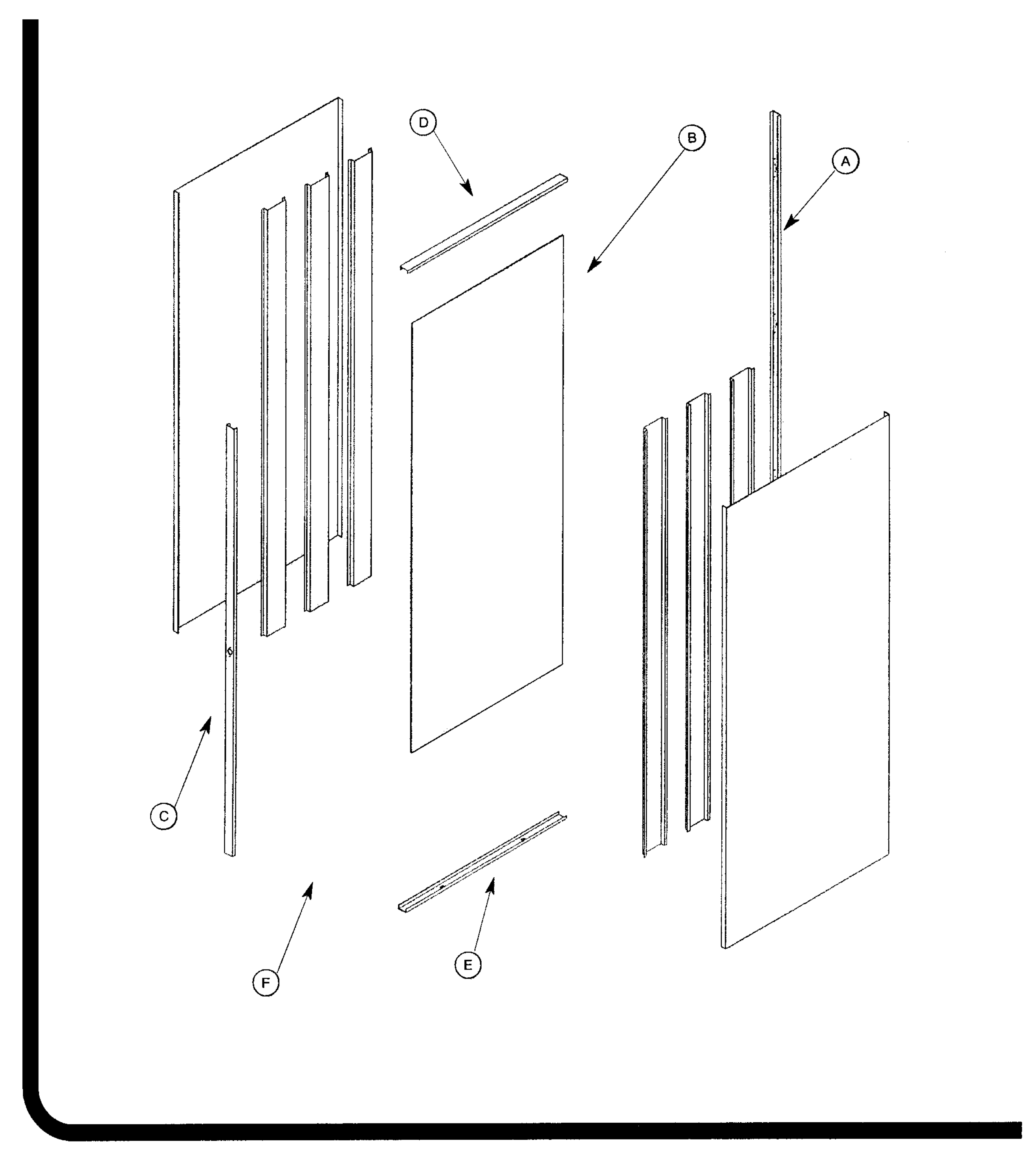
6. Adjust the RBP-870 with the adjustment screws for the desired seal and operation of the door.

7. Check operation of the door after each piece of material is installed to make sure that no binding is taking place.

By permission, Republic Doors and Frame, McKenzie, TN.

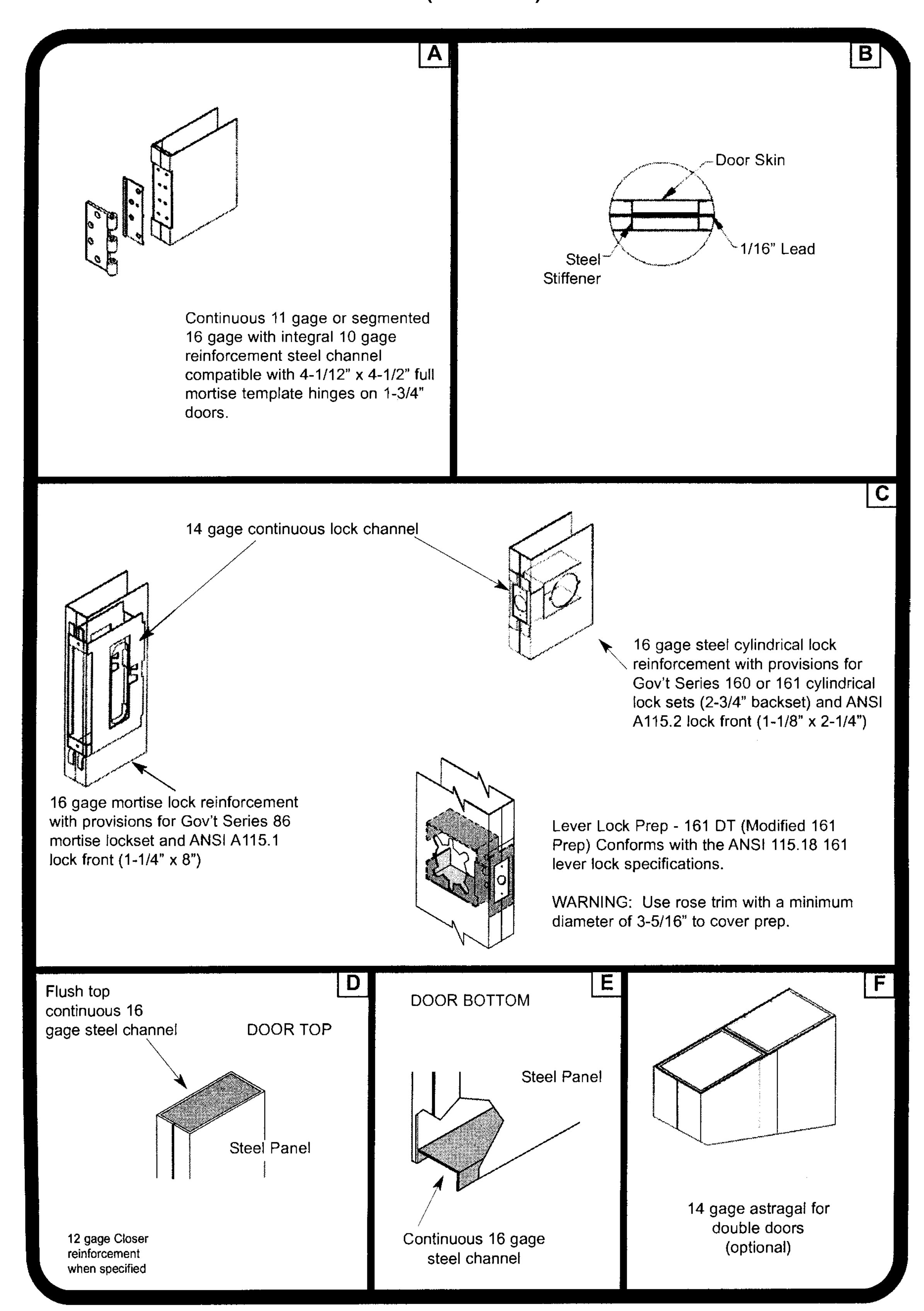
7.1.15 Lead-Lined Hollow Metal Door Construction

LEAD LINED DOOR CONSTRUCTION DETAILS



By permission, Republic Doors and Frame, McKenzie, TN.

7.1.15 Lead-Lined Hollow Metal Door Construction (Continued)

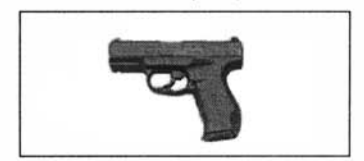


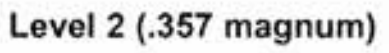
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.16 Bullet-Resistant Hollow Metal Frames—Protection Levels per UL752

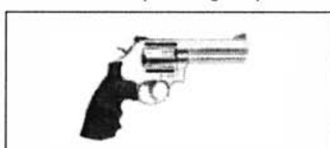
Protection Levels per UL752

Level 1 (9mm)

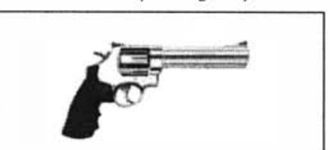




Level 2 (.357 magnum)



Level 3 (.44 magnum)

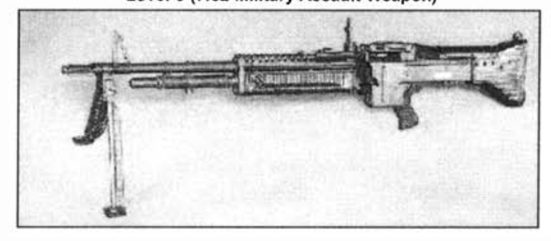


Level	No. of Shots	Ammunition	Grain	Min. Velocity	Results
1	19	9mm full metal copper jacket	124	1,256 fps	Pass
3	19	.44 Magnum lead semi-wad cutter gas checked	240	1,350 fps	Pass
4	19	.30 caliber rifle lead core	180	2,540 fps	Pass
5	5	7.62mm rifle full metal jacket military ball	150	2,750 fps	Pass
6	5	9mm full metal jacket	124	1,400 fps	Pass
7	12	5.56mm rifle full metal jacket	55	3,080 fps	Pass
8	12	7.62mm rifle full metal jacket military ball	150	2,750 fps	Pass
Supplementary shotgun	3	12 ga. Rifled lead slug	437	1,585 fps	Pass

Features

- SDI Level 4 - Maximum Duty - Performance Level A
- Flush top channel standard for exterior applications
- All doors have insulated polystyrene or mineral wool core as standard
- Fire Labeling up to 3 hours
- Seamless vertical edges (visible optional)
- Pairs available (up to level 3) - (7 gage astragal required)
- Sidelights and transoms available (consult factory)
- 4-1/2", 5" and continuous hinge preparations available
- Glass lights available (consult factory)
- Gov 86 or Gov 161 lock preparations available

Level 8 (7.62 Military Assault Weapon)



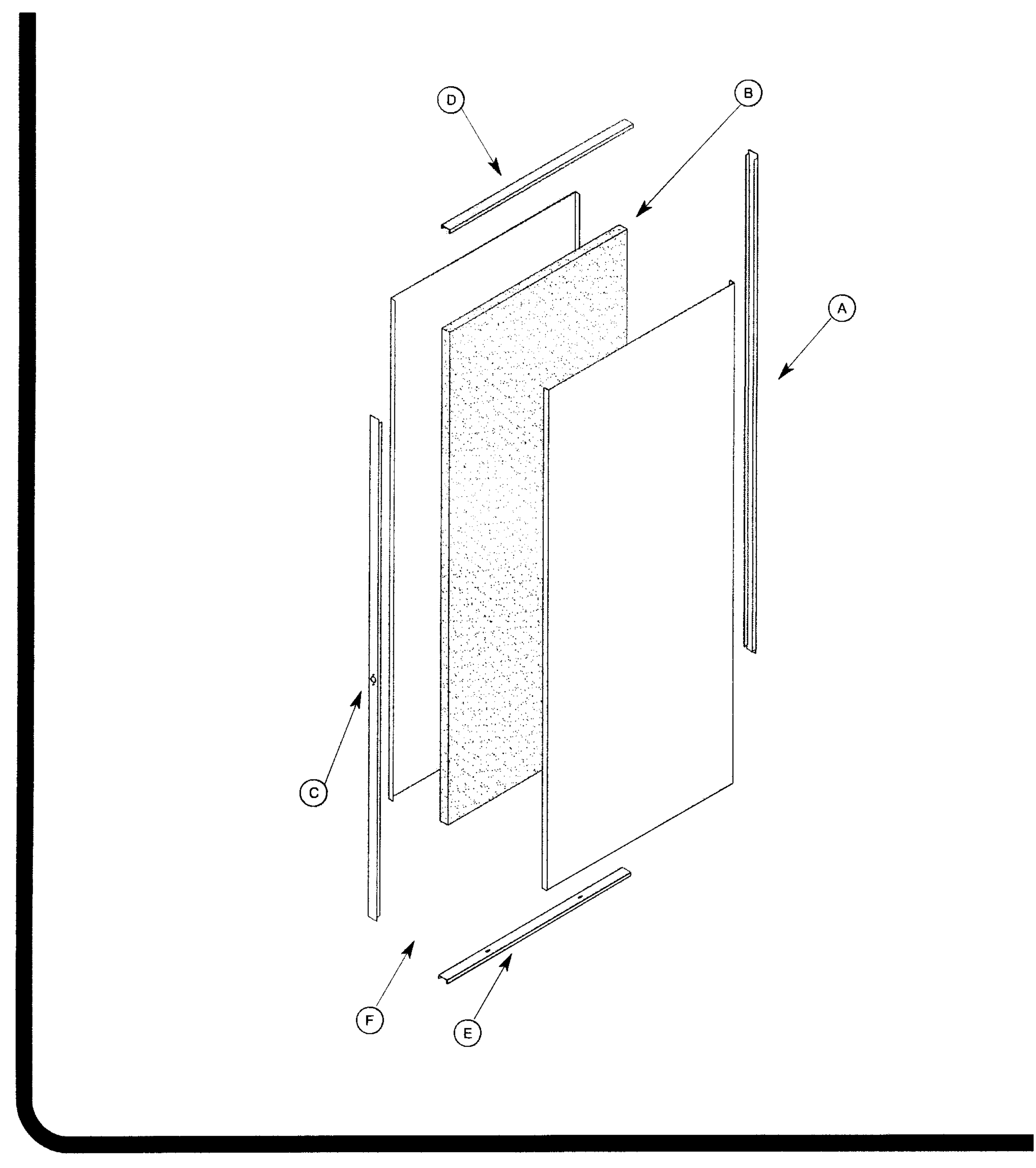
Testing & Certification:

All door & frame assemblies tested in accordance with: UL 752-1995

Testing was performed by: Intertek Testing Services

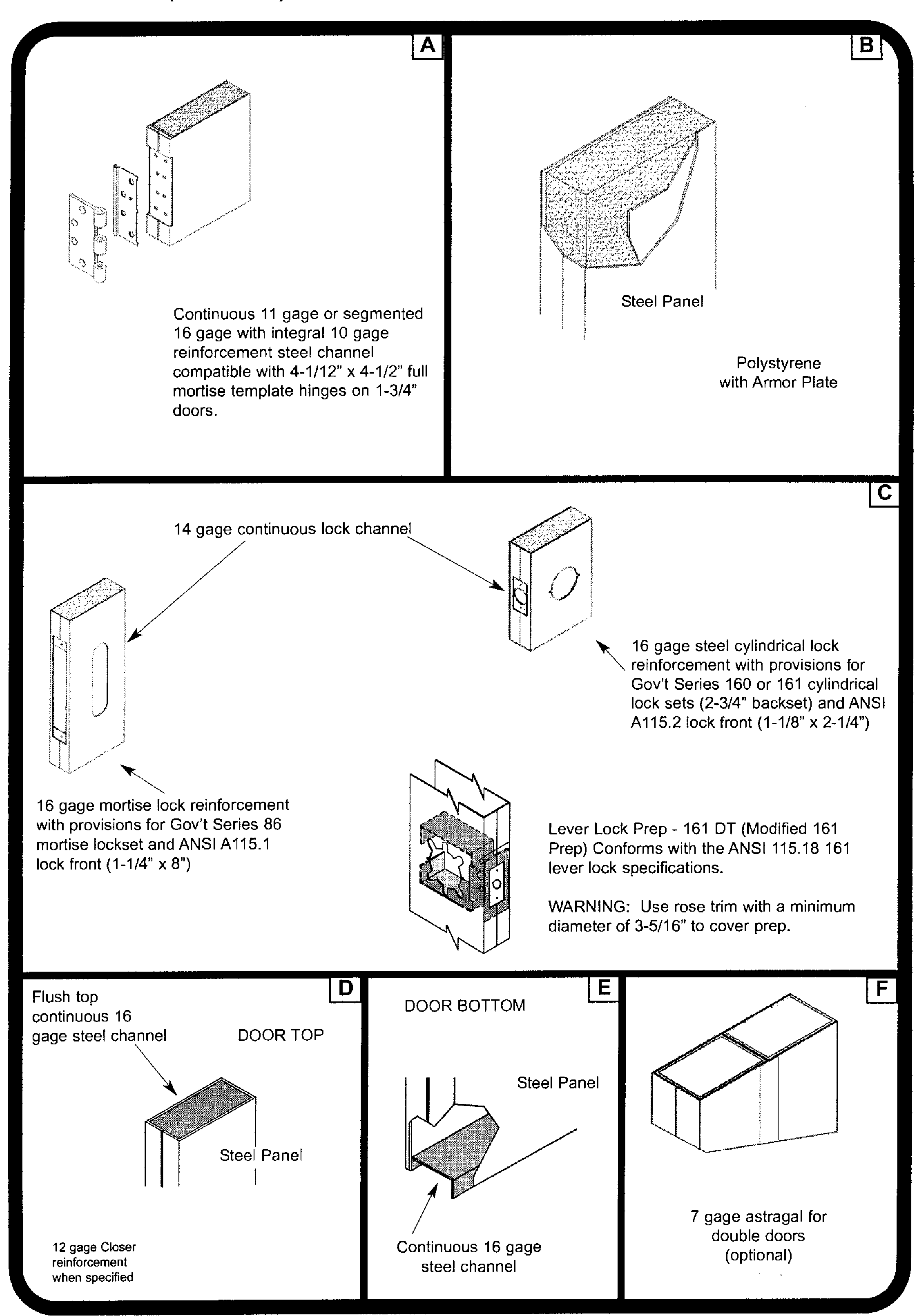
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.16.1 Level 1



By permission, Republic Doors and Frame, McKenzie, TN.

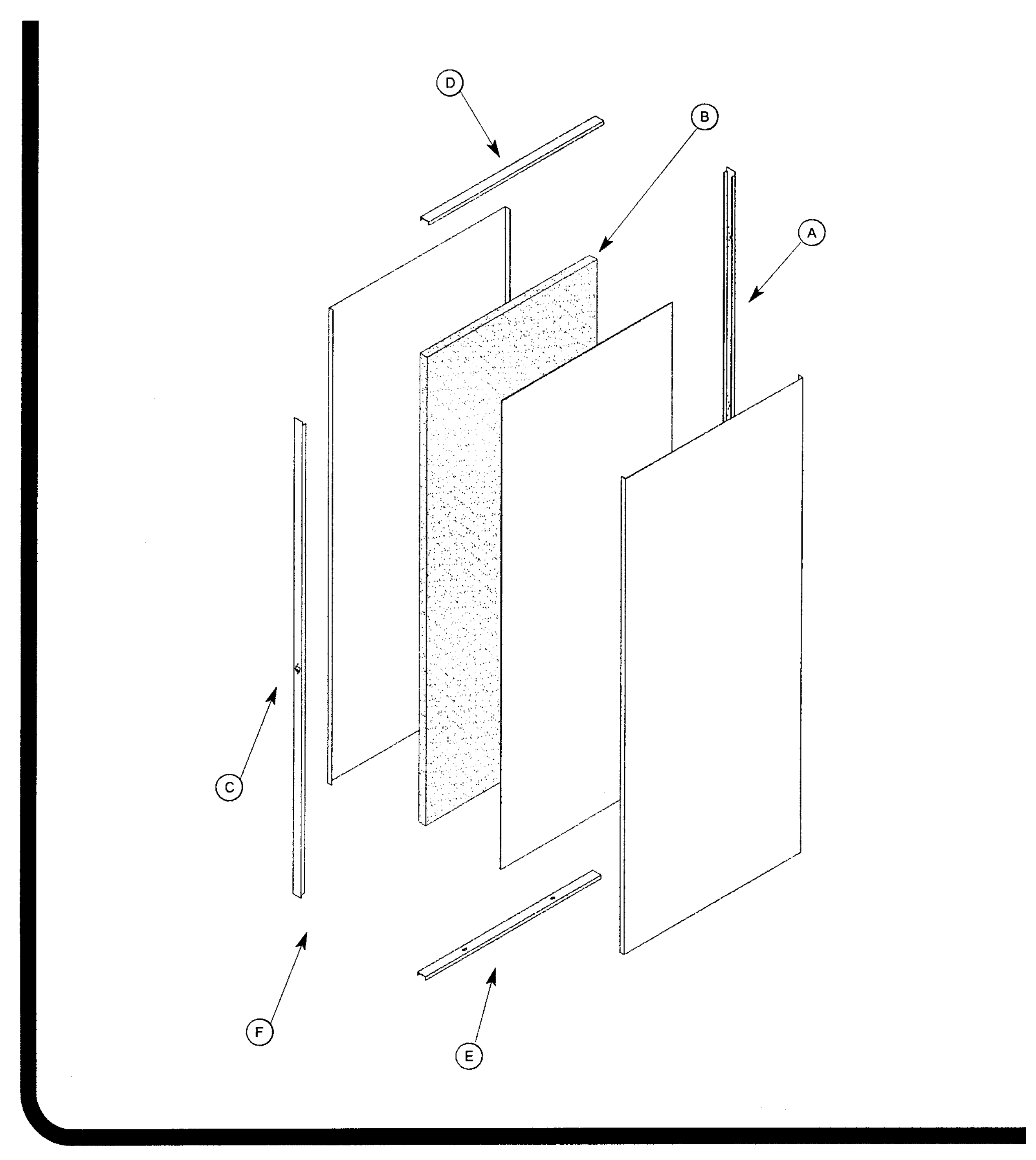
7.1.16.1 Level 1 (Continued)



By permission, Republic Doors and Frame, McKenzie, TN.

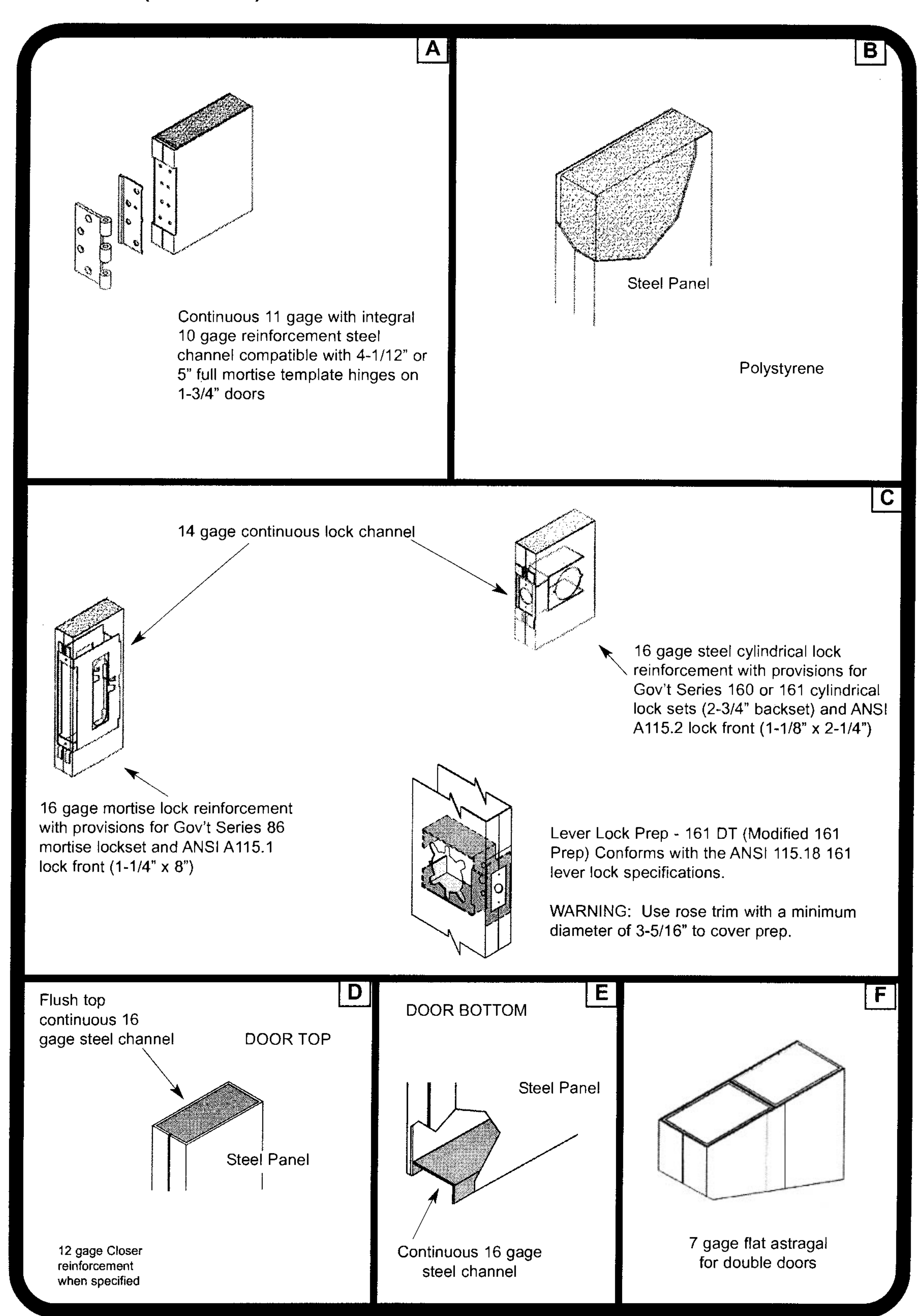
7.1.16.2 Levels 2 and 3

BULLET RESISTANT DOOR CONSTRUCTION - LEVEL 2 & 3



By permission, Republic Doors and Frame, McKenzie, TN.

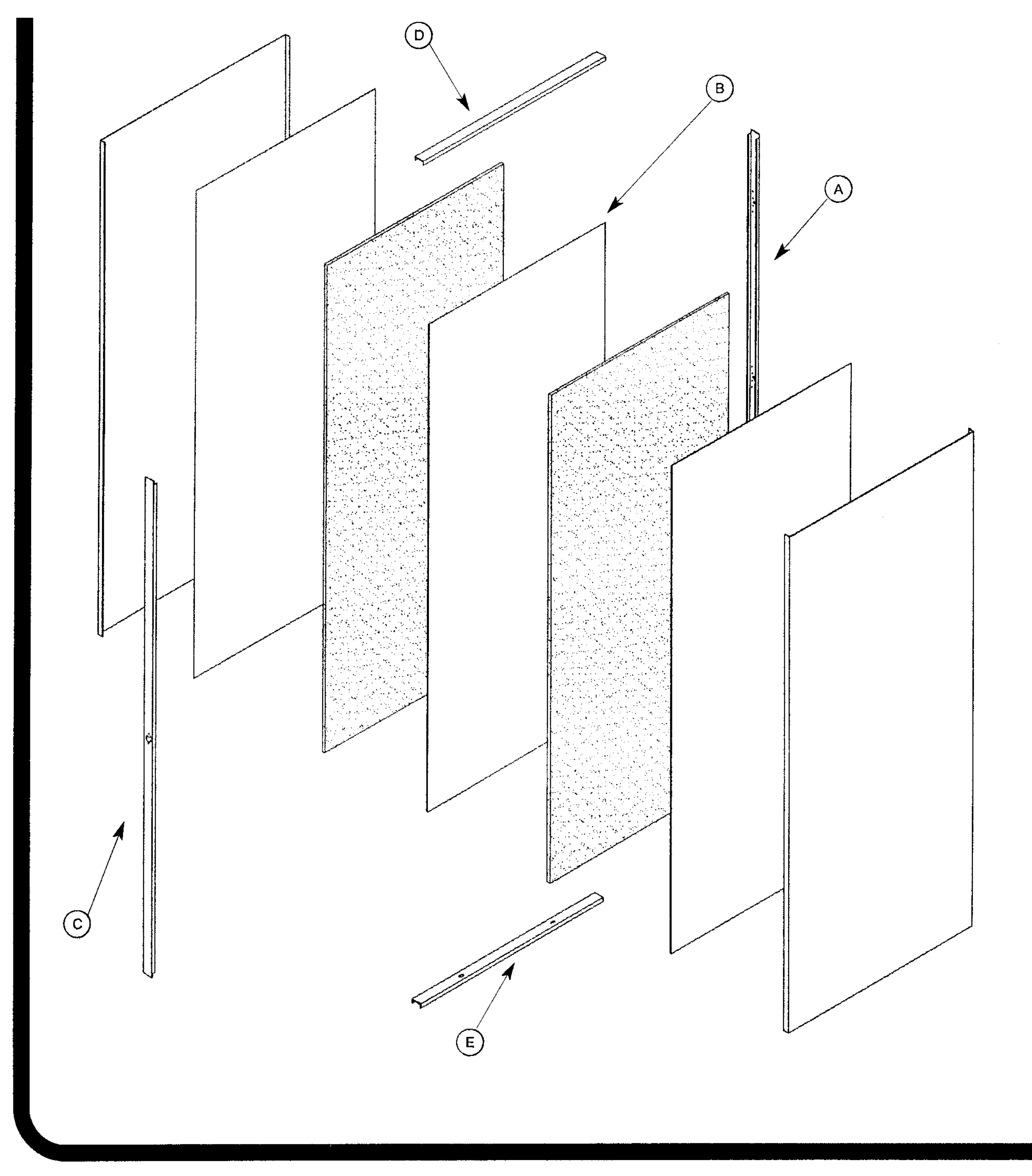
7.1.16.2 Levels 2 and 3 (Continued)



By permission, Republic Doors and Frame, McKenzie, TN.

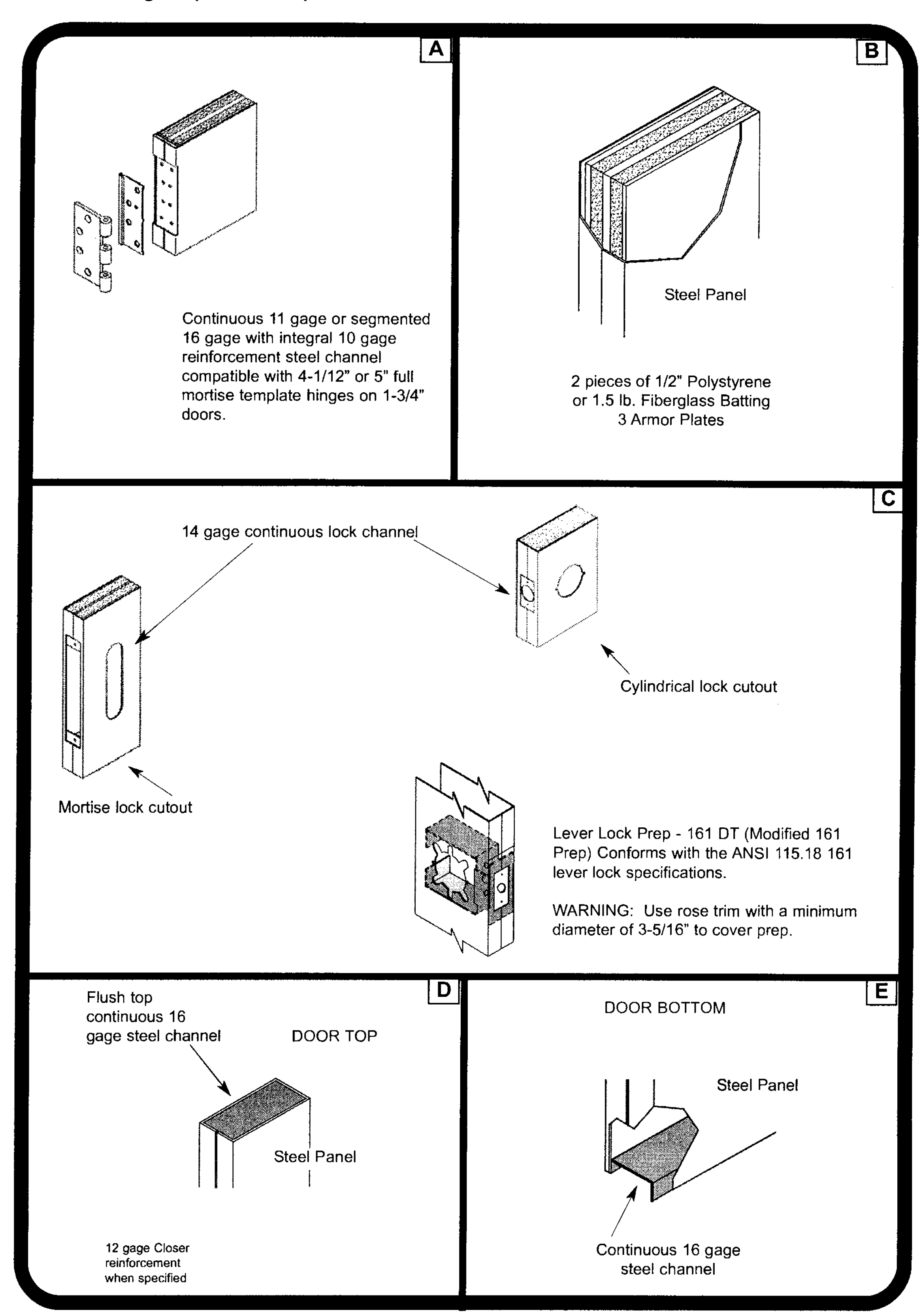
7.1.16.3 Levels 4 through 8

BULLET RESISTANT DOOR CONSTRUCTION - LEVEL 4 THRU 8



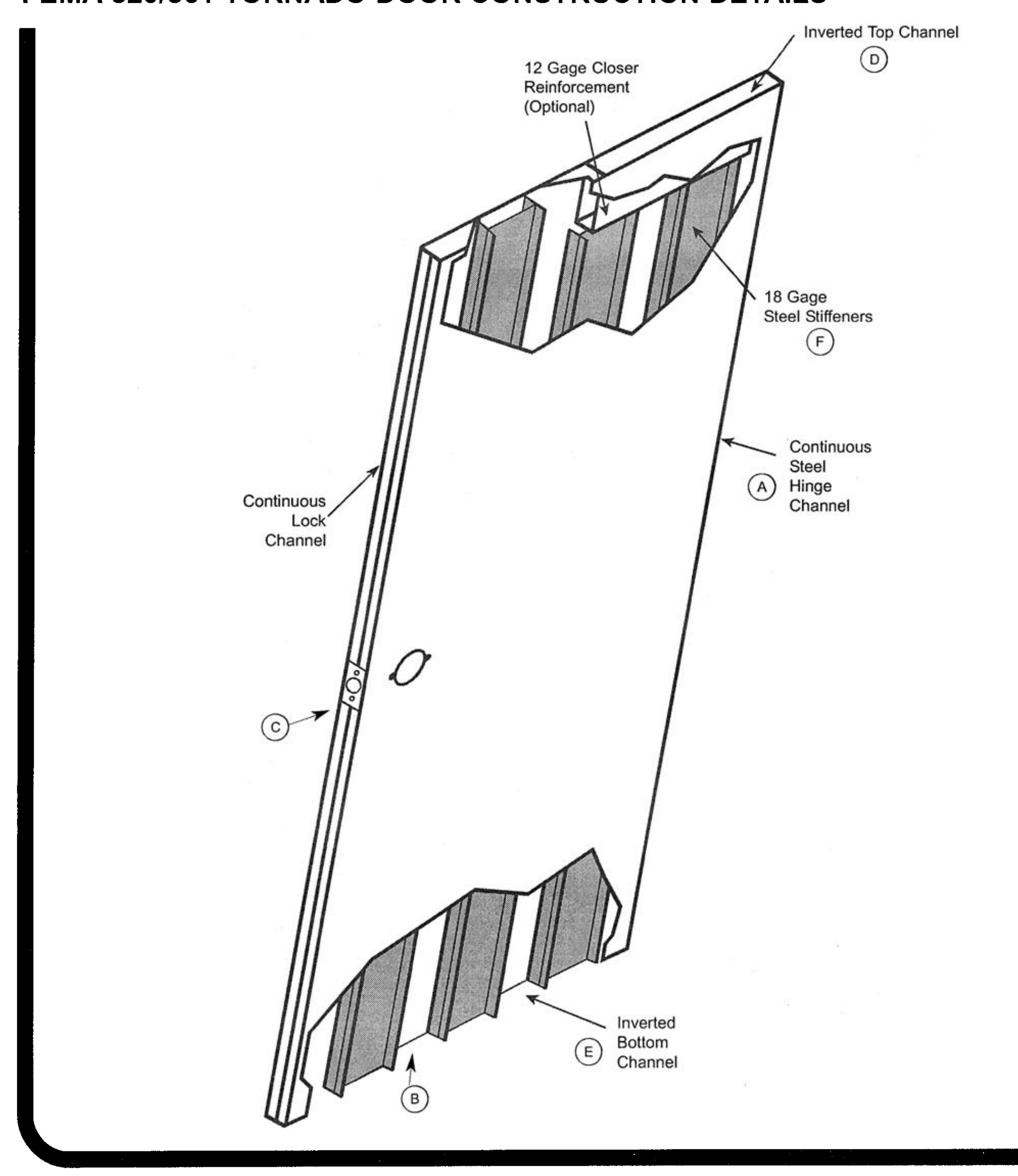
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.16.3 Levels 4 through 8 (Continued)



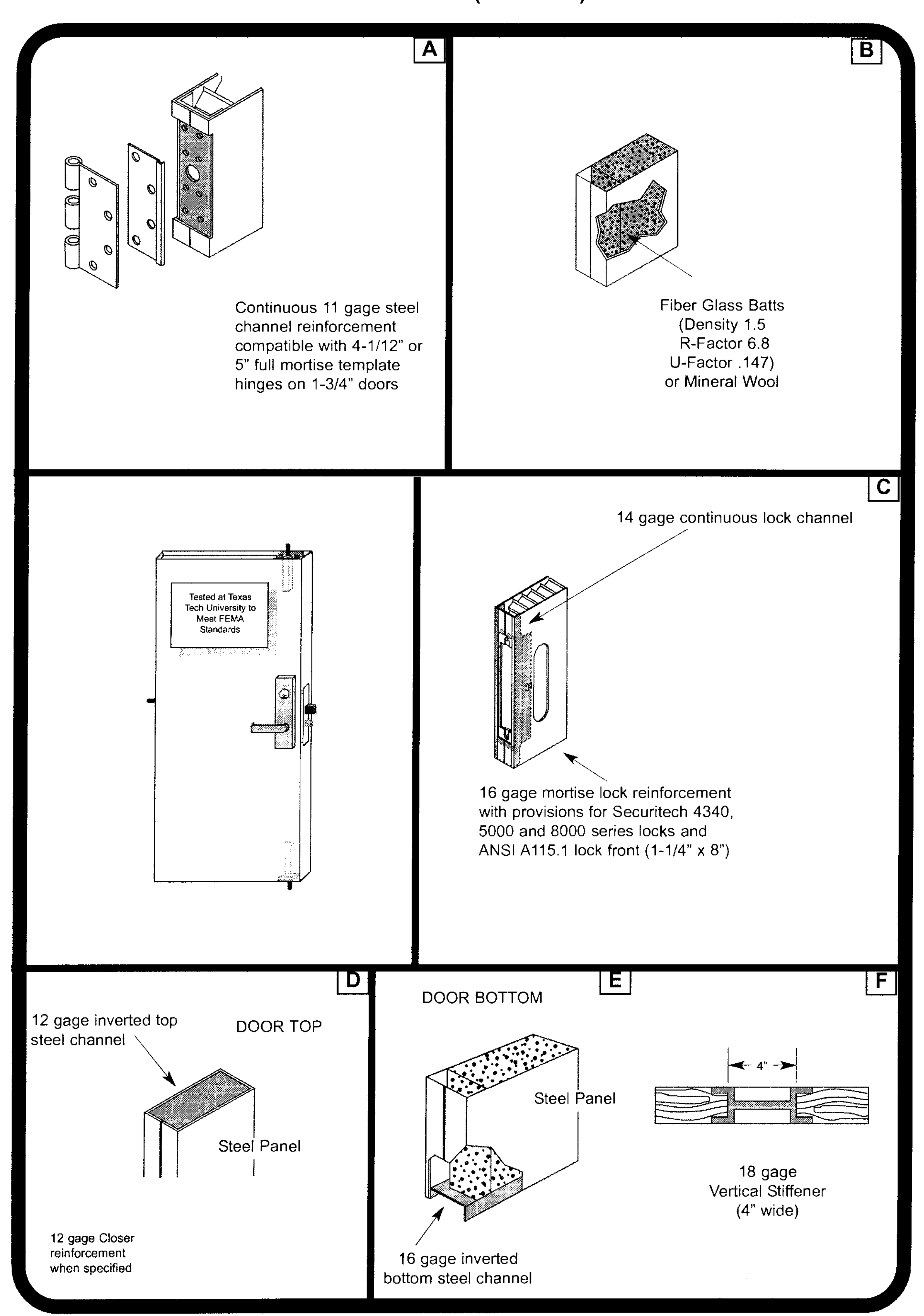
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.17 FEMA Tornado-Rated Hollow Metal Doors



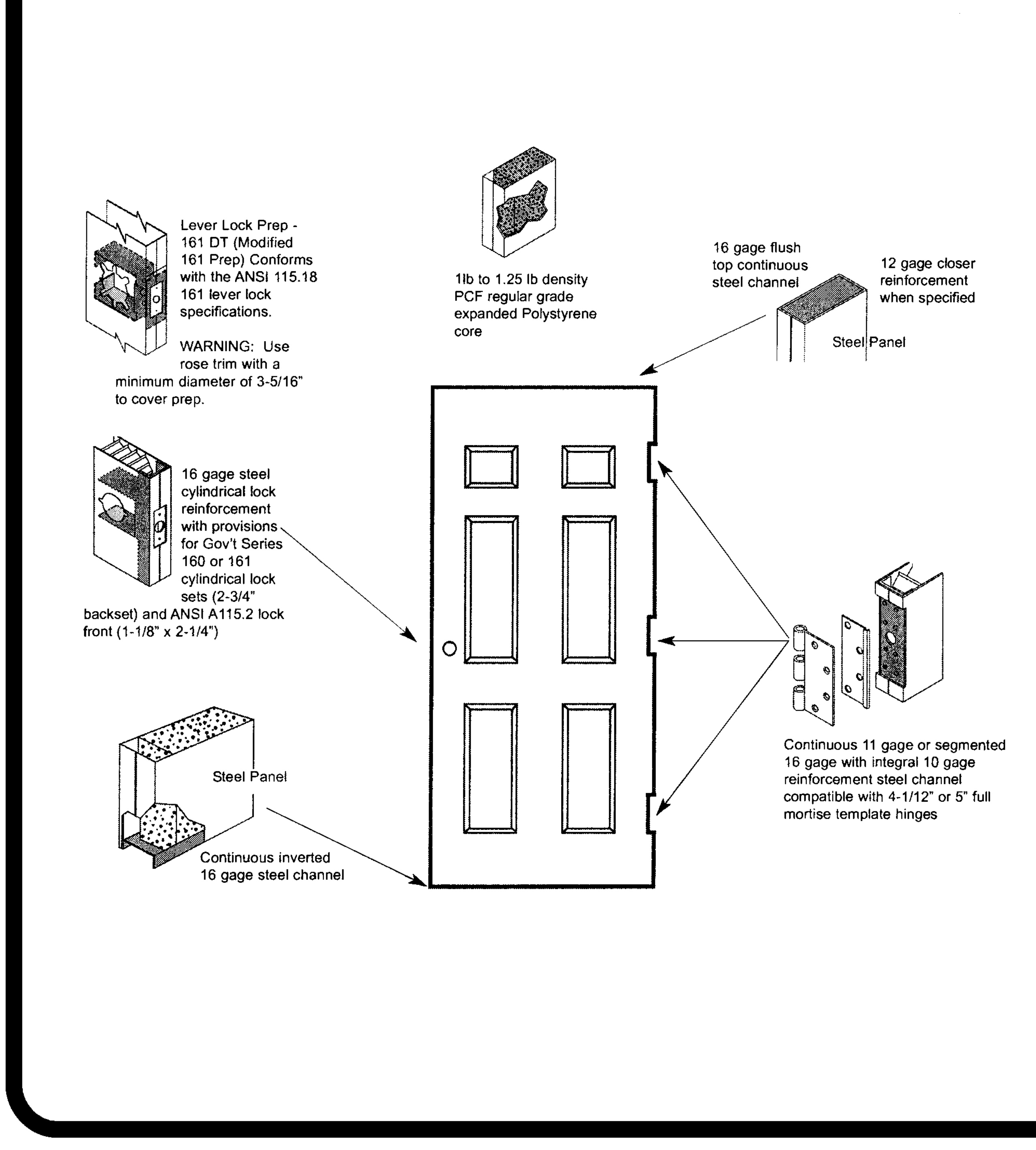
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.17 FEMA Tornado-Rated Hollow Metal Doors (Continued)



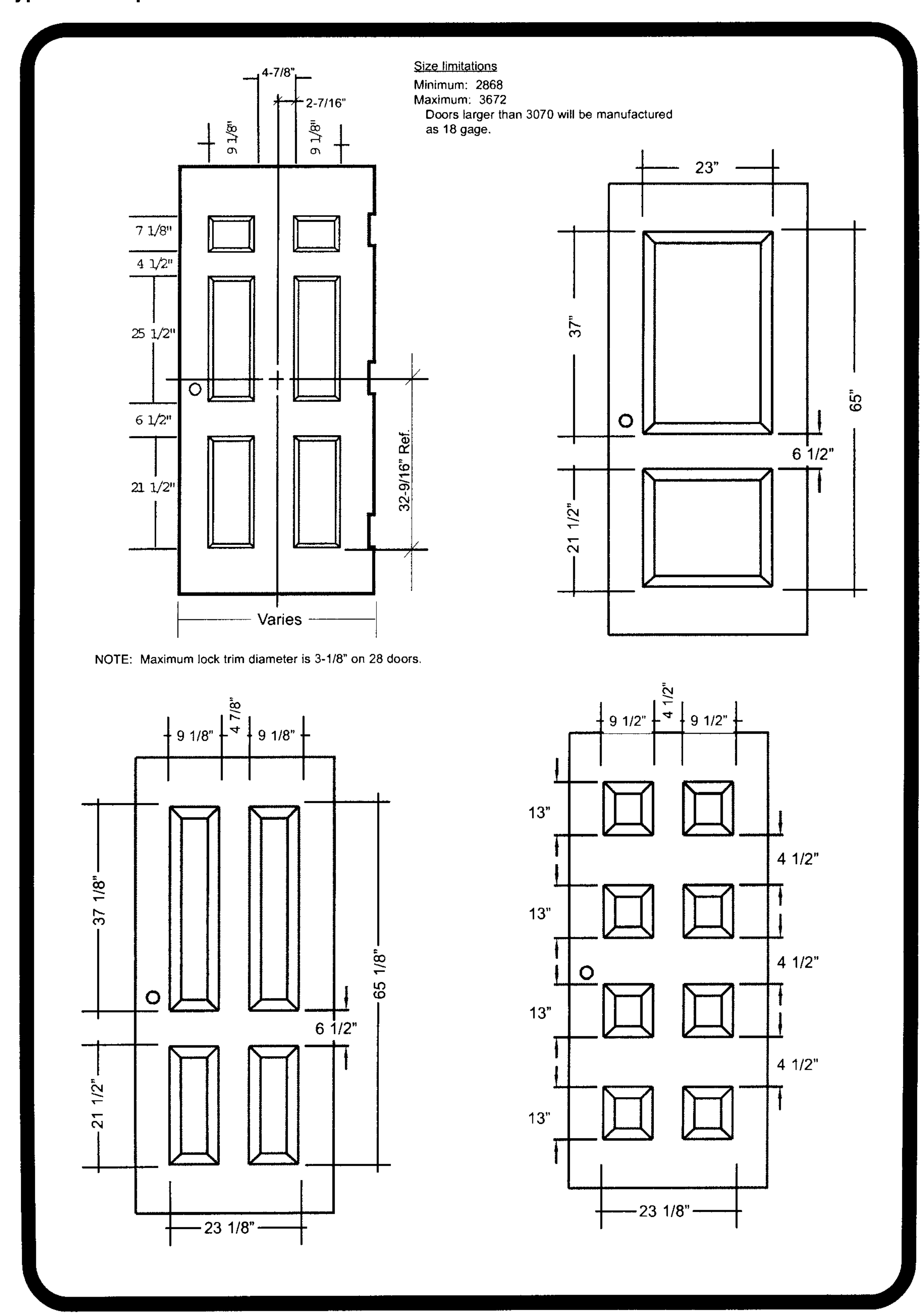
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.18 Embossed Hollow Metal Doors



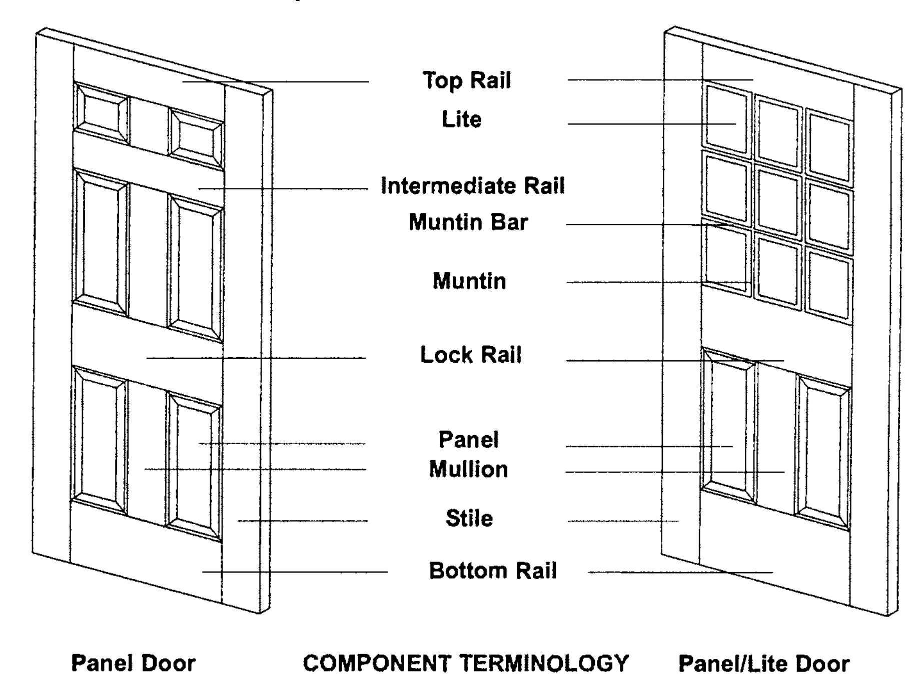
By permission, Republic Doors and Frame, McKenzie, TN.

7.1.18.1 Typical Examples of Embossed Door Faces



By permission, Republic Doors and Frame, McKenzie, TN.

7.2.0 Paneled Wood Door Components



By permission, Woodwork Institute, West Sacramento, CA.

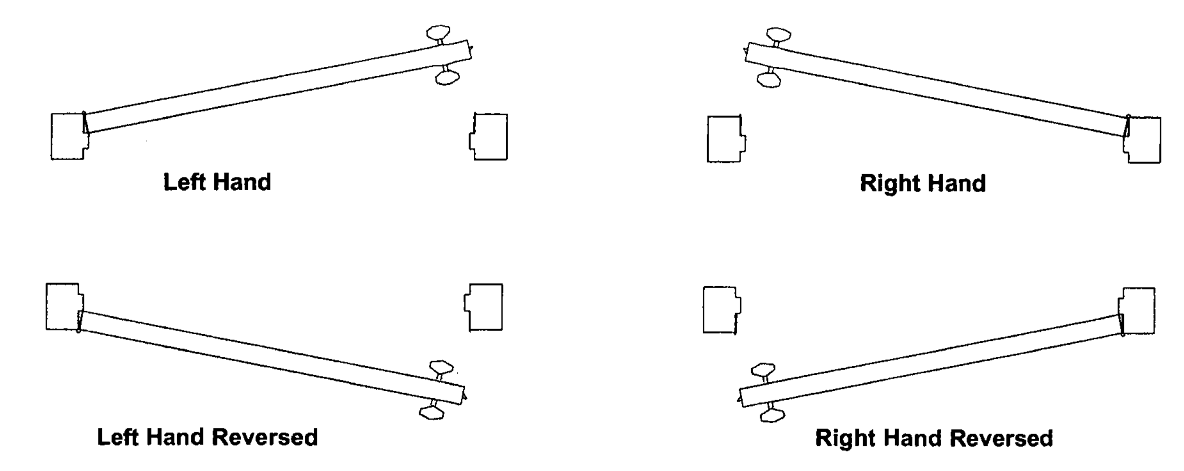
7.2.1 Door Handing Determination

1.4 **HANDING** follows the following basic rules:

1.4.1 The outside of an exterior door is the key side.

1.4.2 The outside of an interior door is the key side or imaginary key side.

1.4.3 The outside of a closet door is the side away from the closet.



HAND OF DOOR IS ALWAYS DETERMINED FROM THE OUTSIDE

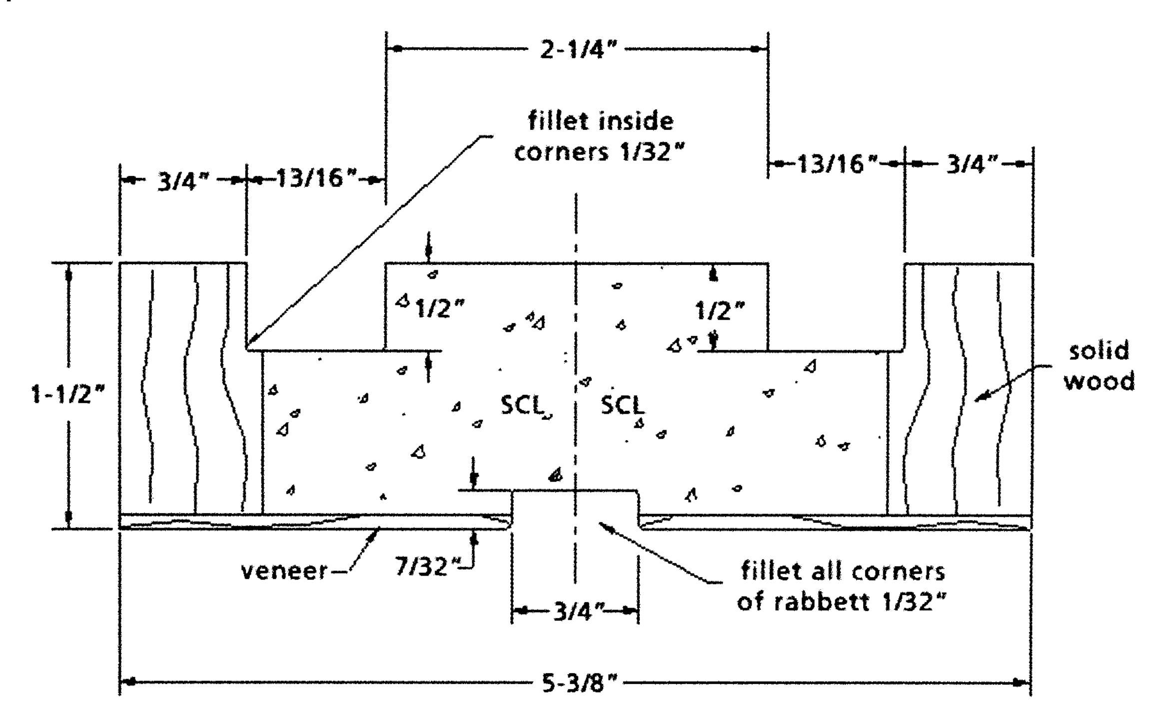
1.5 **HARDWOOD** and **SOFTWOOD** doors shall be of special design and construction.

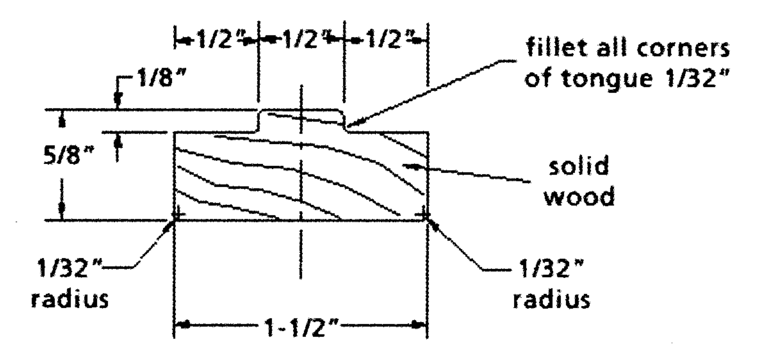
1.6 **PANEL DOORS** consist of stiles, rails and one or more panels.

1.7 **GLAZED OR FRENCH DOORS** consist of stiles, rails and one or more lights but may also contain one or more panels.

By permission, Woodwork Institute, West Sacramento, CA.

7.2.2 Typical Wood Door Jamb Profile



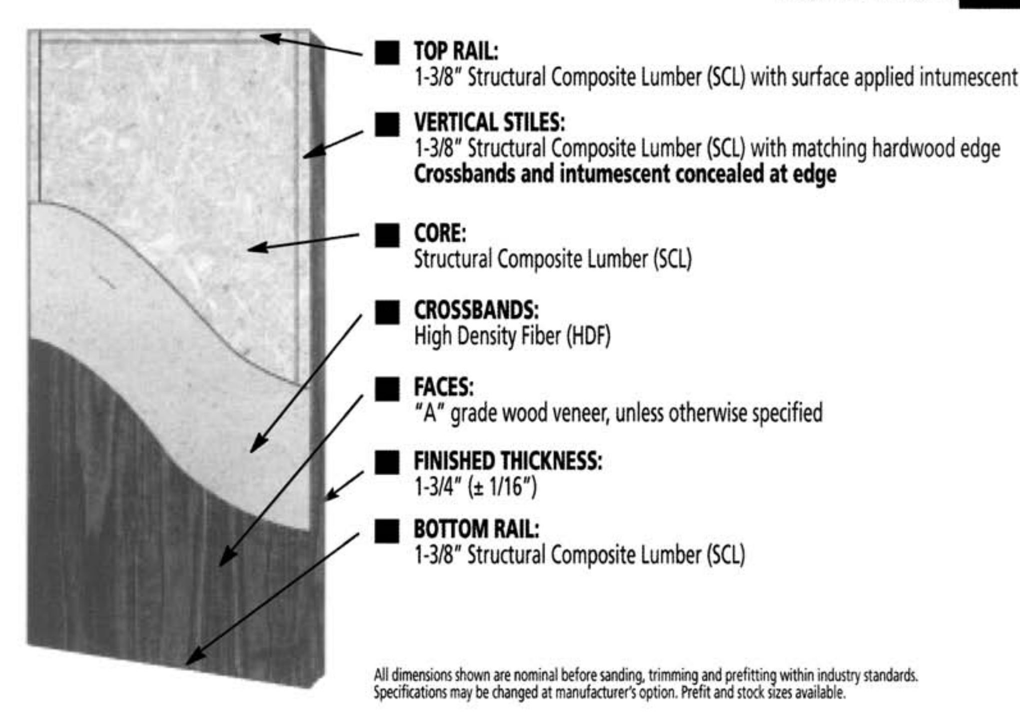


By permission, VT Industries, Holstein, IA.

7.2.3 Wood Veneer—Composite Lumber Core Flush Door Construction

WOOD VENEER
BONDED STRUCTURAL COMPOSITE LUMBER CORE
5-PLY CONSTRUCTION
20- OR 45-MINUTE*
POSITIVE PRESSURE

5P08
VT Door Type
SCLC-20PP-5 • SCLC-45PP-5
(Interior use only)



WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: WDMA TR-6, Catalyzed Polyurethane Factory Finish

Veneer Match: Book match standard. Slip or random available if specified.

Veneer Face Assembly: Running match standard. Center or balanced available if specified.

Pairs and Sets: Pair match, set match available

Doors/Transoms: Door and transom match

Vertical Edges: (visible surface) Matching hardwood finished at factory (-2) with edge-before-face construction. Optional edges are: unfinished (-1) and stiles primed at factory (-9).

Cutouts: 5" minimum distance from door edge and the minimum distance between lite and lock cut out for 20-minute is 1-1/2" and 5" for 45-minute

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

• ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.

• Top and bottom rails of door shall be factory sealed.

• Doors shall be clad in WDMA premium "A" grade wood veneer with minimum thickness 1/42" before sanding, with Type 1 adhesive. Both domestic and exotic hardwood species available for transparent finish. Mill option face material for opaque finish.

*• Positive pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. 20-minute available as pairs and single doors, 45-minute available as single doors. Positive pressure must be noted at time of bid.

• Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Beige powder coated steel lite frames shall be furnished for lite openings unless otherwise specified. Steel lite frames may be veneer-wrapped at additional cost.

• Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.

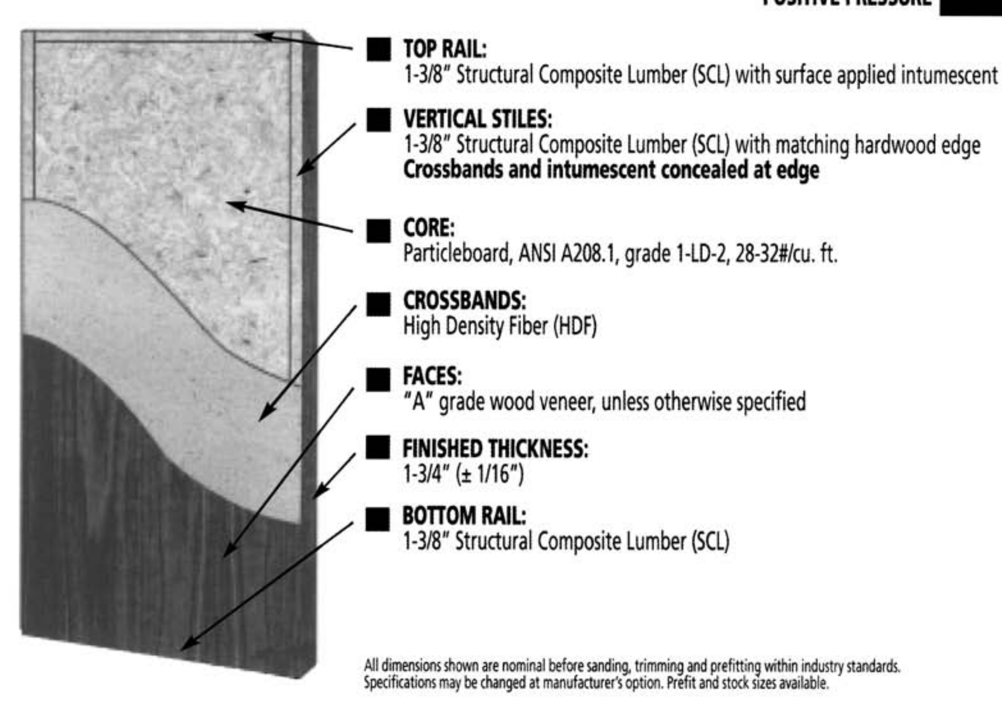
• Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

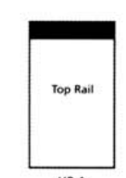
7.2.4 Wood Veneer—Bonded Particleboard Core Construction

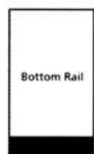
WOOD VENEER
BONDED PARTICLEBOARD CORE
5-PLY CONSTRUCTION
20-MINUTE
POSITIVE PRESSURE

5P02
VT Door Type
PC-20PP-5
(Interior use only)



Blocking Reinforcement Options: available at additional cost for undercutting and specialized hardware. Blocking recommended for Extra Heavy Duty Doors using surface mounted hardware.





WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: WDMA TR-6, Catalyzed Polyurethane Factory Finish

Veneer Match: Book match standard. Slip or random available if specified.

Veneer Face Assembly: Running match standard. Center or balanced available if specified.

Pairs and Sets: Pair match, set match available

Doors/Transoms: Door and transom match

Vertical Edges: (visible surface) Matching hardwood finished at factory (-2) with edge-before-face construction. Optional edges are: unfinished (-1) and stiles primed at factory (-9).

Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

• ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.

• Top and bottom rails of door shall be factory sealed.

• Doors shall be clad in WDMA premium "A" grade wood veneer with minimum thickness 1/42" before sanding, with Type 1 adhesive. Both domestic and exotic hardwood species available for transparent finish. Mill option face material for opaque finish.

• Positive pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Positive pressure must be noted at time of bid.

• Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Beige powder coated steel lite frames shall be furnished for lite openings unless otherwise specified. Steel lite frames may be veneer-wrapped at additional cost.

• Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.

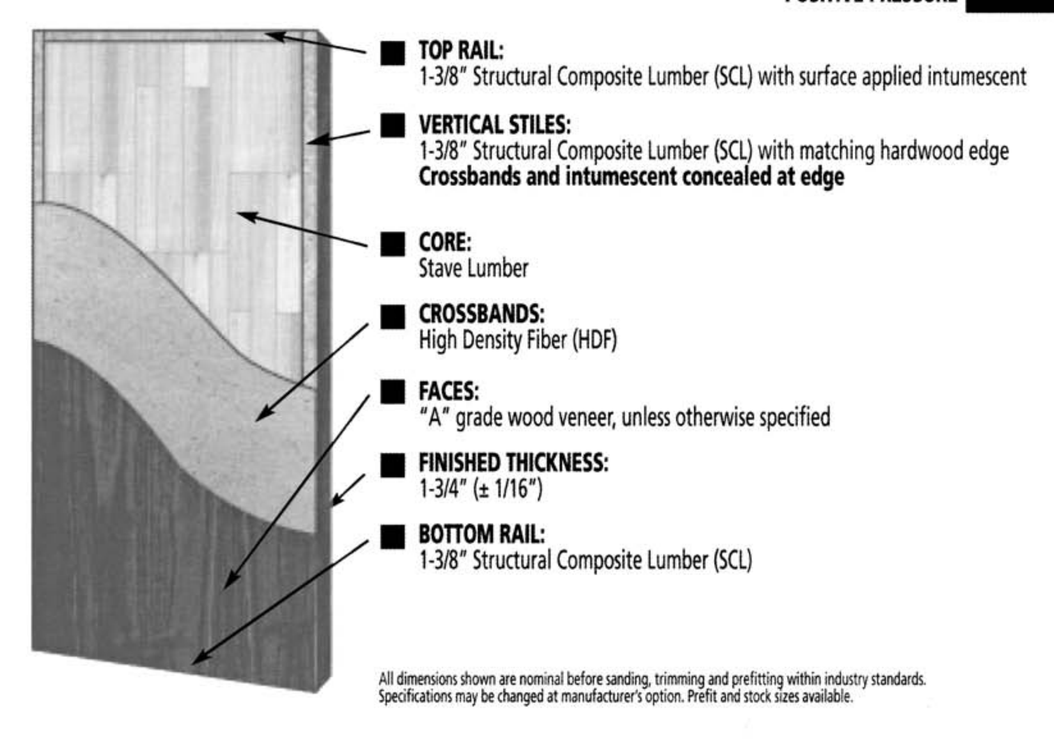
• Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

7.2.5 Wood Veneer—Bonded Stave Core Construction

WOOD VENEER
BONDED STAVE LUMBER CORE
5-PLY CONSTRUCTION
20-MINUTE
POSITIVE PRESSURE

5P07
VT Door Type
SLC-20PP-5
(Interior use only)



No blocking required.

WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: WDMA TR-6, Catalyzed Polyurethane Factory Finish

Veneer Match: Book match standard. Slip or random available if specified.

Veneer Face Assembly: Running match standard. Center or balanced available if specified.

Pairs and Sets: Pair match, set match available

Doors/Transoms: Door and transom match

Vertical Edges: (visible surface) Matching hardwood finished at factory (-2) with edge-before-face construction. Optional edges are: unfinished (-1) and stiles primed at factory (-9).

Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

• ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.

• Top and bottom rails of door shall be factory sealed.

• Doors shall be clad in WDMA premium "A" grade wood veneer with minimum thickness 1/42" before sanding, with Type 1 adhesive. Both domestic and exotic hardwood species available for transparent finish. Mill option face material for opaque finish.

• Positive pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Positive pressure must be noted at time of bid.

• Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Beige powder coated steel lite frames shall be furnished for lite openings unless otherwise specified. Steel lite frames may be veneer-wrapped at additional cost.

• Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.

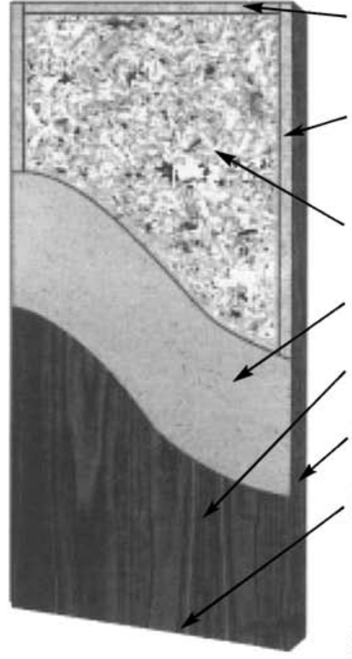
• Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

7.2.6 Wood Veneer—Agrifiber Core, 20-, 45-, 60-Minute Fire-Rated Door Construction

WOOD VENEER
BONDED AGRIFIBER CORE
5-PLY CONSTRUCTION
20-, 45- OR 60-MINUTE
POSITIVE PRESSURE





TOP RAIL:
1-3/8" Structural Composite Lumber (SCL) with surface applied intumescent (as shown), or 1-1/2" Firestop™ for 45-minute pairs, and 60-minute singles

VERTICAL STILES:
1-3/8" Structural Composite Lumber (SCL) with matching hardwood edge (as shown), or 1-1/2" Firestop™ stile, 3" lock stile for 45-minute pairs and 1-1/2" Firestop™ stiles for 60-minute singles
Crossbands and intumescent concealed at edge

CORE:
Agrifiber Board, ANSI A208.1, grade 1-LD-2, 28-32#/cu. ft.

CROSSBANDS:
High Density Fiber (HDF)

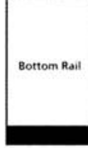
FACES:
"A" grade wood veneer, unless otherwise specified

FINISHED THICKNESS:
1-3/4" (± 1/16")

BOTTOM RAIL:
1-3/8" Structural Composite Lumber (SCL) (as shown), or 1-1/2" G.P. Firestop™ with 45-minute pairs and 60-minute singles

All dimensions shown are nominal before sanding, trimming and prefitting within industry standards. Specifications may be changed at manufacturer's option. Prefit and stock sizes available.

Blocking Reinforcement Options: available at additional cost for undercutting and specialized hardware. Blocking recommended for Extra Heavy Duty Doors using surface mounted hardware.



WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: WDMA TR-6, Catalyzed Polyurethane Factory Finish

Veneer Match: Book match standard. Slip or random available if specified.

Veneer Face Assembly: Running match standard. Center or balanced available if specified.

Pairs and Sets: Pair match, set match available

Doors/Transoms: Door and transom match

Vertical Edges: (visible surface) Matching hardwood finished at factory (-2) with edge-before-face construction. Optional edges are: unfinished (-1) and stiles primed at factory (-9).

Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

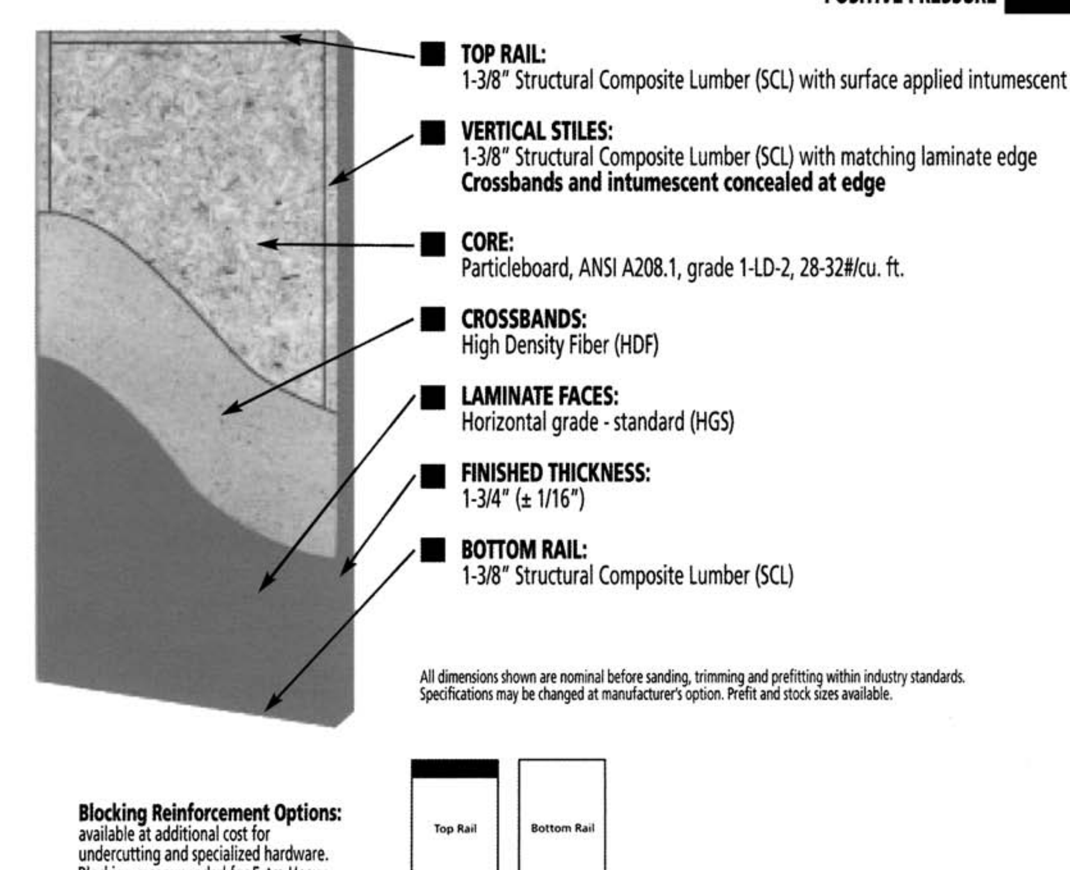
- ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.
- Top and bottom rails of door shall be factory sealed.
- Doors shall be clad in WDMA premium "A" grade wood veneer with minimum thickness 1/42" before sanding, with Type 1 adhesive. Both domestic and exotic hardwood species available for transparent finish. Mill option face material for opaque finish.
- Positive pressure 20-, 45-, 60-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Positive pressure must be noted at time of bid.
- Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Primed steel lite frames shall be furnished for lite openings. Steel lite frames may be veneer-wrapped at additional cost.
- Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.
- Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

7.2.7 High-Pressure Laminate (HPL) Faced Bonded Particleboard Door Construction

HIGH PRESSURE DECORATIVE LAMINATE
BONDED PARTICLEBOARD CORE
5-PLY CONSTRUCTION
20-MINUTE
POSITIVE PRESSURE





Blocking Reinforcement Options: available at additional cost for undercutting and specialized hardware. Blocking recommended for Extra Heavy Duty Doors using surface mounted hardware.

Top Rail — HB-1 | Bottom Rail — HB-2

WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: Woodgrains, Solid Colors & Patterns

Laminate Face: Horizontal grade - standard (HGS)

Vertical Edges: (visible surface) Same as face material laminated (-3) with edge-before-face construction. Optional edges are: unfinished (-1), finished at factory (-2), and painted at factory (-4) with a mill option hardwood edges for staining or painting.



Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

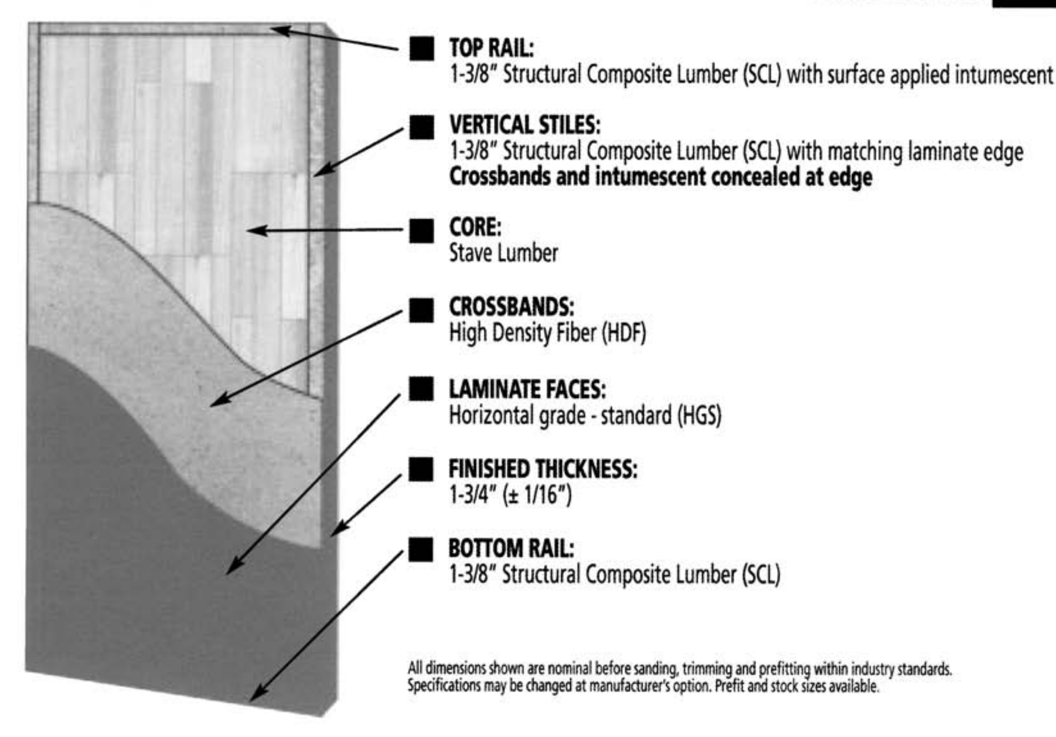
DOOR STANDARDS:

- ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.
- Top and bottom rails of door shall be factory sealed.
- Doors shall be clad in horizontal grade standard high pressure decorative laminate, meeting or exceeding NEMA Standard LD3, Type HGS, with Type 1 adhesive. Standard colors and patterns may be selected, or custom colors and patterns can be specified at additional cost.
- Positive pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Positive pressure must be noted at time of bid.
- Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Beige powder coating steel lite frames shall be furnished for lite openings.
- Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.
- Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

7.2.8 HPL Faced Bonded Stave Lumber Core Construction

HIGH PRESSURE DECORATIVE LAMINATE
BONDED STAVE LUMBER CORE
5-PLY CONSTRUCTION
20-MINUTE
POSITIVE PRESSURE





No blocking required.

WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: Woodgrains, Solid Colors & Patterns

Laminate Face: Horizontal grade - standard (HGS)

Vertical Edges: (visible surface) Same as face material laminated (-3) with edge-before-face construction. Optional edges are: unfinished (-1), finished at factory (-2), and painted at factory (-4) with a mill option hardwood edges for staining or painting.



Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

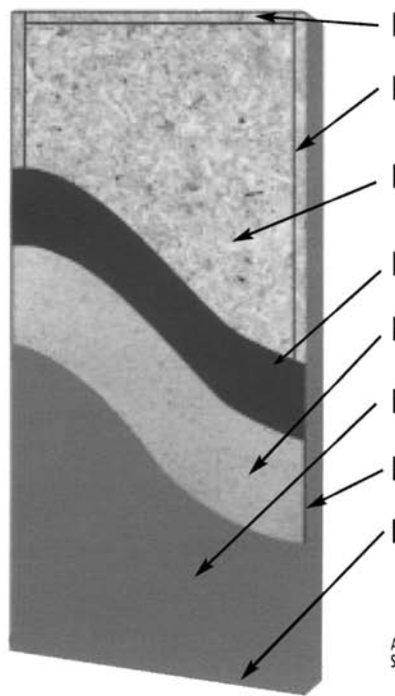
- ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.
- Top and bottom rails of door shall be factory sealed.
- Doors shall be clad in horizontal grade standard high pressure decorative laminate, meeting or exceeding NEMA Standard LD3, Type HGS, with Type 1 adhesive. Standard colors and patterns may be selected, or custom colors and patterns can be specified at additional cost.
- Positive pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Positive pressure must be noted at time of bid.
- Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Primed steel lite frames shall be furnished for lite openings.
- Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.
- Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

7.2.9 HPL Lead-Lined Door Construction

HIGH PRESSURE DECORATIVE LAMINATE
BONDED PARTICLEBOARD CORE • LEAD-LINED
7-PLY CONSTRUCTION
20-MINUTE
POSITIVE PRESSURE



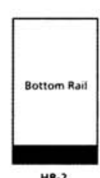


- **TOP RAIL:**
  3-3/8" Structural Composite Lumber (SCL) with surface-applied intumescent
- **VERTICAL STILES:**
  1-3/8" Structural Composite Lumber (SCL) with matching laminate edge
  Crossbands and intumescent concealed at edge
- **CORE:**
  Particleboard, ANSI A208.1, grade 1-LD-2, 28-32#/cu. ft. with continuous lead glued to each side of framed core
- **LEAD SHEETS:**
  1/16" to 1/4" thick
- **CROSSBANDS:**
  High Density Fiber (HDF)
- **LAMINATE FACES:**
  Horizontal grade - standard (HGS)
- **FINISHED THICKNESS:**
  1-3/4" (± 1/16")
- **BOTTOM RAIL:**
  3-3/8" Structural Composite Lumber (SCL)

All dimensions shown are nominal before sanding, trimming and prefitting within industry standards.
Specifications may be changed at manufacturer's option. Prefit and stock sizes available.

Blocking Reinforcement Options: available at additional cost for undercutting and specialized hardware. Blocking recommended for Extra Heavy Duty Doors using surface mounted hardware.

Top Rail
HB-1



WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: Woodgrains, Solid Colors & Patterns

Laminate Face: Horizontal grade - standard (HGS)

Vertical Edges: (visible surface) Same as face material laminated (-3) with edge-before-face construction. Optional edges are: unfinished (-1), finished at factory (-2), and painted at factory (-4) with a mill option hardwood edges for staining or painting.

Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

DOOR STANDARDS:

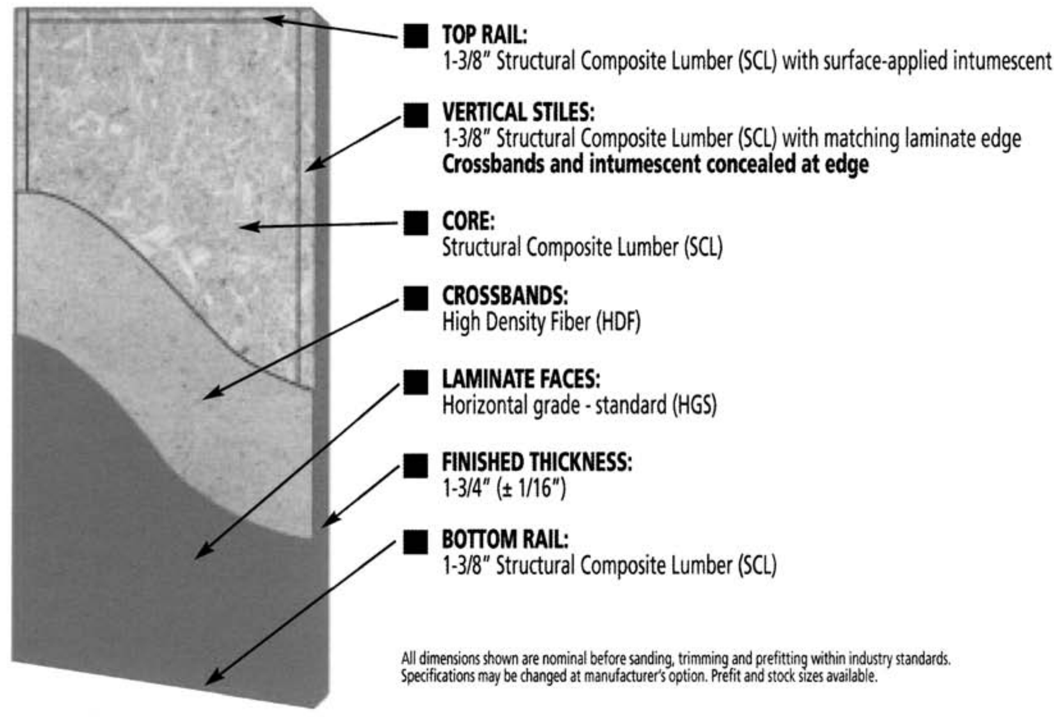
- ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core).
- Top and bottom rails of door shall be factory sealed.
- Doors shall be clad in horizontal grade standard high pressure decorative laminate, meeting or exceeding NEMA Standard LD3, Type HGS, with Type 1 adhesive. Standard colors and patterns may be selected, or custom colors and patterns can be specified at additional cost.
- Neutral pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Neutral pressure must be noted at time of bid.
- Positive pressure fire label is available on 20-minute single doors going into welded or knockdown steel frames. Surface-applied smoke gasketing, such as Pemko S88, must be applied to frame to achieve "S" rating (gasketing to be supplied by others). Listed & labeled steel lite frames must be used for lite openings. Positive pressure must be noted at time of bid.
- Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Maximum length or width shall not exceed 16", nor will the maximum area exceed 256 square inches. Lead-lined steel lite frames shall be furnished for lite openings.
- Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

7.2.10 HPL 20- and 45-Minute Fire-Rated Door Construction

HIGH PRESSURE DECORATIVE LAMINATE
BONDED STRUCTURAL COMPOSITE LUMBER CORE
5-PLY CONSTRUCTION
20- OR 45-MINUTE*
POSITIVE PRESSURE





All dimensions shown are nominal before sanding, trimming and prefitting within industry standards. Specifications may be changed at manufacturer's option. Prefit and stock sizes available.

No blocking required.

WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: Woodgrains, Solid Colors & Patterns

Laminate Face: Hortizontal grade - standard (HGS)

Vertical Edges: (visible surface) Same as face material laminated (-3) with edge-before-face construction. Optional edges are: unfinished (-1), finished at factory (-2), and painted at factory (-4) with a mill option hardwood edges for staining or painting.



Cutouts: 5" minimum distance from door edge and the minimum distance between lite and lock cut out for 20-minute is 1-1/2" and 5" for 45-minute.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

- ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.
- Top and bottom rails of door shall be factory sealed.
- Doors shall be clad in horizontal grade standard high pressure decorative laminate, meeting or exceeding NEMA Standard LD3, Type HGS, with Type 1 adhesive. Standard colors and patterns may be selected, or custom colors and patterns can be specified at additional cost.

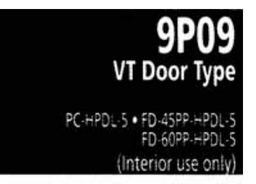
*• Positive pressure 20-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. 20-minute available as pairs and single doors, 45-minute available as single doors. Positive pressure must be noted at time of bid.

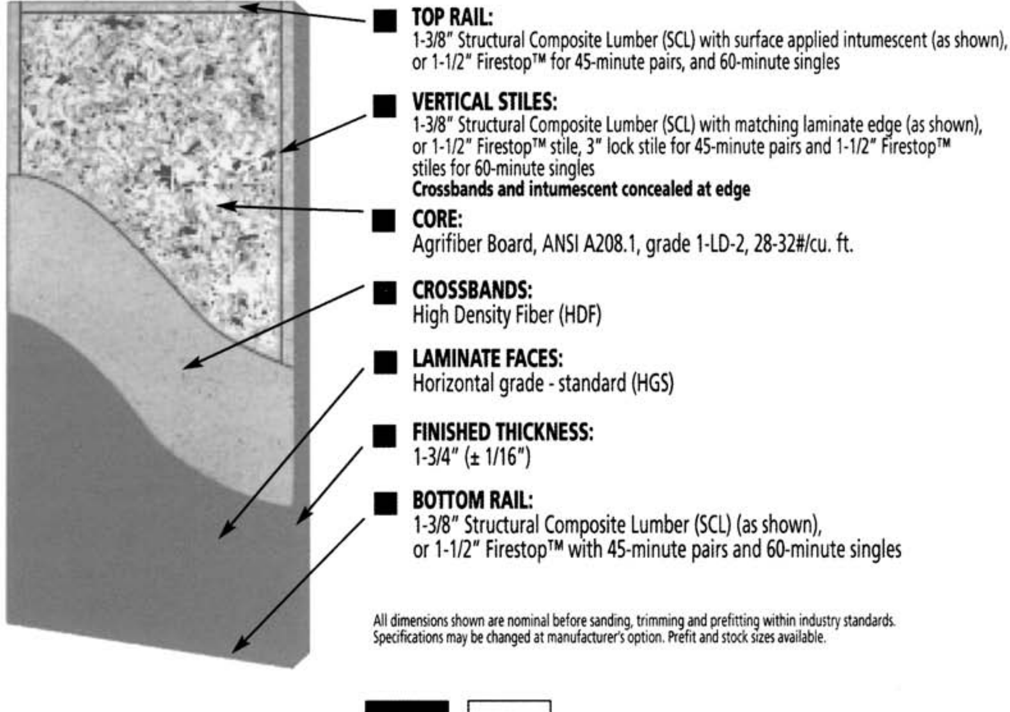
- Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Beige powder coated steel frames shall be furnished for lite openings.
- Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.
- Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

7.2.10.1 HPL 20-, 45-, and 60-Minute Fire-Rated Door Construction

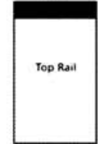
HIGH PRESSURE DECORATIVE LAMINATE
BONDED AGRIFIBER CORE
5-PLY CONSTRUCTION
20-, 45- OR 60-MINUTE
POSITIVE PRESSURE

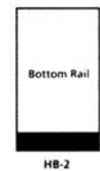




All dimensions shown are nominal before sanding, trimming and prefitting within industry standards. Specifications may be changed at manufacturer's option. Prefit and stock sizes available.

Blocking Reinforcement Options: available at additional cost for undercutting and specialized hardware. Blocking recommended for Extra Heavy Duty Doors using surface mounted hardware.





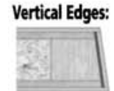
WDMA PREMIUM GRADE EXTRA HEAVY DUTY DOOR

DOOR FEATURES:

Finish Type: Woodgrains, Solid Colors & Patterns

Laminate Face: Horizontal grade - standard (HGS)

Vertical Edges: (visible surface) Same as face material laminated (-3) with edge-before-face construction. Optional edges are: unfinished (-1), finished at factory (-2), and painted at factory (-4) with a mill option hardwood edges for staining or painting.



Cutouts: 3-5/16" minimum distance between lite and lock cutout and 5" minimum distance from door edge.

Standard Bevel: 1/8" in 2"

Clearances: 1/8" top, 1/8" lock and hinge stiles. See NFPA-80 6.3.1.7, 2007 edition, for bottom clearances.

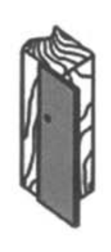
Security Rating: Class 40 (highest rating possible)

DOOR STANDARDS:

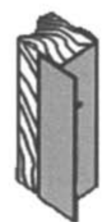
- ANSI/WDMA I.S. 1-A and AWI Section 1300 Quality Standards (Bonded Core). UBC 7-2-1997, Parts I and II. IBC 2000. UL 10-C.
- Top and bottom rails of door shall be factory sealed.
- Doors shall be clad in horizontal grade standard high pressure decorative laminate, meeting or exceeding NEMA Standard LD3, Type HGS, with Type 1 adhesive. Standard colors and patterns may be selected, or custom colors and patterns can be specified at additional cost.
- Positive pressure 20-, 45-, 60-minute Intertek/Warnock Hersey fire labels shall be available within size and usage limitations. Fire-rated doors must use approved lite frames. Louvers are prohibited in 20-minute fire doors. Positive pressure must be noted at time of bid.
- Cutouts for vision panels and louvers shall be made at the factory and shall be of sizes and locations as indicated on the drawings. Beige powder coated steel lite frames shall be furnished for lite openings unless otherwise specified.
- Hardware preparation: All cutouts for mortise hardware shall be made at the factory from hardware manufacturer's templates and approved shop drawings.
- Doors shall be individually poly-bagged for protection in transit and storage periods, and shall be marked as per tag openings on shop drawings.

By permission, VT Industries, Holstein, IA.

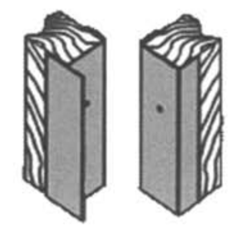
7.3.0 Commonly Used Astragals and Edge Sets for Wood Doors



FBA 1-1/2-inch (1-1/2") flat bar astragal (FBA) typically furnished with 20-minute pairs of doors.

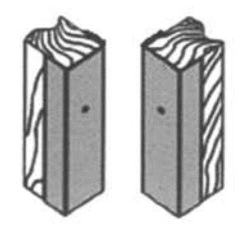


204L 1-inch (1") "h" shaped astragal typically furnished with lead-lined doors.

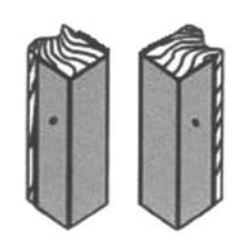


207 1-inch (1") legged metal channel & "h" shaped astragal set typically furnished with 45-, 60-, and 90-minute pairs of single egress doors.

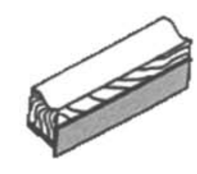
For double egress pairs use a 209.



208 1-inch (1") legged metal channel set typically furnished with 45-, 60-, and 90-minute pairs where surface vertical rod or rim exit devices are used.



251 5-inch (5") legged metal channel set typically furnished with all single doors or pairs of doors with a concealed vertical rod exit device.

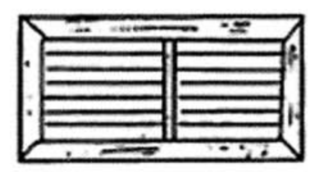


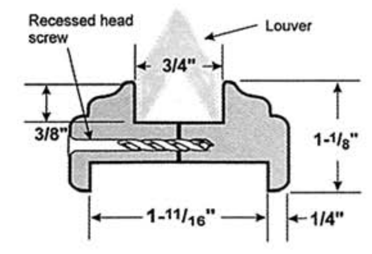
DTA Door/transom "T" shaped astragal typically furnished with straight cut 20-minute units where no fixed bar occurs between the door and transom. Negative Pressure only.

By permission, VT Industries, Holstein, IA.

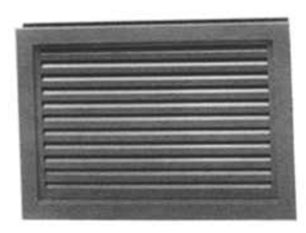
7.3.1 Standard Louver Installation Details for Wood Doors

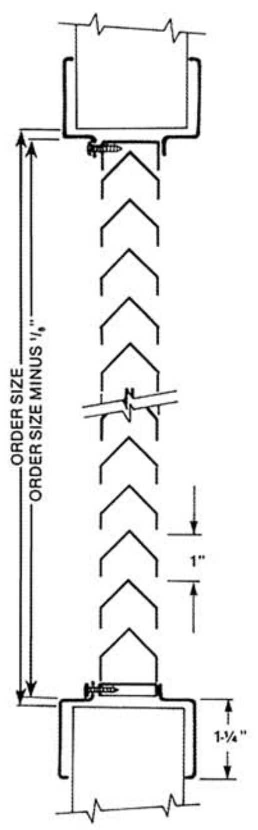
Wood Louver
Regular
for non-rated doors
Variety of Species





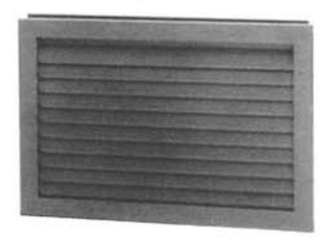
Metal Louver
800-A1
for non-rated doors
Grey Prime

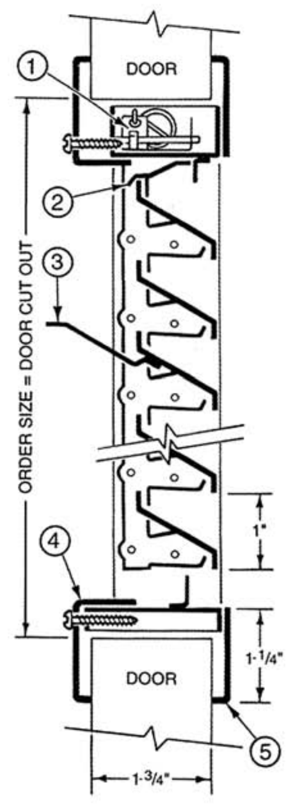




Vandal-proof design; basic blade unit with flanged frame welded to face (corridor) side and separate removable flanged frame on opposite side

Metal Louver
1900-A
for 45-, 60-, 90-minute doors
Grey Prime





1. Heat-actuated closure mechanism with 135°
2. Fusible link
3. Integral blade stop holds blades in open position
4. Adjusting tab
5. Adjusting mounting flange frame
6. Fixed face frame

NOTES:

- 20-minute doors with louvers are not allowed.
- Give all louver dimensions as width x height.
- Refer to Product Update #P104F for more details.

By permission, VT Industries, Holstein, IA.

7.3.2 Care and Storage of Wood Doors at the Jobsite

How to Store, Handle, Finish, Install and Maintain Wood Doors

Preface: Improper storage, handling, finishing and installation of wood doors may result in severe damage to the doors. The following guidelines will help to maintain the high quality products supplied by wood door manufacturers.

A. Storage and Handling

- Store doors flat on a level surface in a dry, well-ventilated building. Doors should be kept at least 3-1/2" off the floor and should have protective coverings under the bottom door and over the top. Covering should protect doors from dirt, water and abuse but allow for air circulation under and around the stack. Avoid exposure to direct sunlight
- Certain species (e.g., Cherry, Mahogany, walnut, teak) are more susceptible to discoloration if exposed to either sunlight or some forms of artificial light. To protect doors from light damage after delivery, opaque plastic wrapping of individual doors should be specified.
- Do not subject interior doors to extremes of heat and/or humidity. Prolonged exposure may cause damage. Buildings where humidity and temperature are controlled provided the best storage facilities (recommended conditions 30–50% RH and 50–90° F.)
- Do not install doors in buildings that have wet plaster or cement unless they have been properly finished. Do not store doors in buildings with excessive moisture content - HVAC systems should be in operation and balanced.
- Doors should always be handled with clean hands or while wearing clean gloves.
- Doors should be lifted and carried when being moved, not dragged across one another.

B. Finishing

- Wood is hygroscopic and dimensionally influenced by changes in moisture content caused by changes within its surrounding environment. To assure uniform moisture exposure and dimensional control all surfaces must be finished equally.
- Doors may not be ready for finishing when initially received. Before finishing, remove all handling marks, raised grain, scuffs, burnishes and other undesirable blemishes by block sanding all surfaces in a horizontal position with a 120, 150 or 180 grit sandpaper. To avoid cross grain scratches, sand with the grain.
- Certain species of wood, particularly oak, contain chemicals which react unfavorably with foreign materials in the finishing system. Eliminate the use of steel wool on bare wood, rusty containers or any other contaminate in the finishing system.
- A thinned coat of sanding sealer should be applied prior to staining to promote a uniform appearance and avoid sharp contrasts in color or a blotchy appearance.
- All exposed wood surfaces must be sealed including top and bottom rails. Cutouts for hardware in exterior doors must be sealed prior to installation of hardware and exposure to weather.
- Dark colored finishes should be avoided on all surfaces if the door is exposed to direct sunlight, in order to reduce the chance of warping or veneer checking.
- Oil based sealers or prime coats provide the best base coat for finishing. If a water-based primer is used it should be an exterior grade product. Note: Water-based coatings on unfinished wood may cause veneer splits, highlight joints and raise wood grain and therefore should be avoided. If a water-based primer is desired, please contact the finish supplier regarding the correct application and use of these products.
- Be sure the door surface being finished is satisfactory in both smoothness and color after each coat. Allow adequate drying time between coats. Desired results are best achieved by following the finish manufacturers' recommendations. Do not finish door until a sample of the finish has been approved.
- Finishes on exterior doors may deteriorate due to exposure to the environment. In order to protect the door it is recommended that the condition of the exterior finish be inspected at least once a year and refinished as needed.
- Note: Certain wood fire doors have fire retardant salts impregnated into various wood components that makes the components more hygroscopic than normal wood. When exposed to high moisture conditions, these salts will concentrate on exposed surfaces and interfere with the finish. Before finishing, reduce moisture content in the treated wood below 11% and remove the salt crystals with a damp cloth followed by drying and light sanding. For further information on fire doors see NWWDA publications regarding Installing, Handling & Finishing Fire Doors.

Source: Window and Door Manufacturers Association.

7.4.0 Builders' Hardware Terminology—Hinges

A Guide to Builders Hardware Terminology: *Hinges*

(Covered In ANSI/BHMA Standard A156.1)

Bearings.

Anti-Friction Bearing. Bearing material between the various moving parts of a hinge

Plain Bearing (non-bearing). When no bearing material is between the various moving parts of a binge.

Butt Hinge. (see Full Mortise Hinge)

Full Mortise Hinge. A hinge having one leaf mortised into the edge of a door and the other leaf mortised into the rabbet edge of a frame.

Full Surface Hinge. A hinge having one leaf attached to the face of a door and the other leaf attached to the face of a door frame.

Half Mortise Hinge. A hinge having one leaf mortised into the edge of a door and the other leaf attached to the face of a door frame.

Half Surface Hinge. A hinge having one leaf attached to the face of a door and the other leaf mortised into the rabbet edge of a door frame.

Hospital Tips. When the ends of a hinge barrel are sloped.

Maximum Security Pin. A hinge pin that cannot be removed when once installed.

Non-Removable Pin. A hinge pin secured by a set screw or other means.

Olive Knuckle Hinge. A pivot hinge with a joint shaped like an olive.

Pivot Hinge. A hinge with a fixed pin and a single joint having a height less than the adjacent hinge leaves.

Raised Barrel. A full mortise hinge having an offset barrel.

Safety Stud. A projecting member on one surface of a full mortise hinge leaf that engages a hole in the opposite leaf when the door is closed.

Slide-In Hinge. A hinge where one or both leaves slide into a cavity prepared in a door or door frame, thus concealing one or both hinge leaves.

Swaging. Offsetting a hinge leaf at the barrel so the surface of the leaf is not tangent to the outer diameter of the barrel.

Swing Clear Hinge. A hinge that swings a door completely clear of the opening when the door is opened 90 to 95 degrees.

7.4.1 Builders' Hardware Terminology—Spring Hinges and Pivots

A Guide to Builders Hardware Terminology: ***Spring Hinges or Pivots***
(Covered in ANSI/BHMA Standard A156.17) Also called Self-Closing Hinges or Pivots

Clamp Flange. A spring hinge flange which wraps around the edge of the door and is fastened with thru-bolts and nuts.

Double Acting. When a door is so arranged to swing in either direction.

Fall Mortise. When one hinge flange or leaf is mortised into the edge of the door and the other to the mortise cutout of the frame.

Full Surface. When one hinge flange or leaf is fastened to the surface of the door and the other to the surface of the frame.

Gravity Pivot Hinge. A pivot hinge arranged so the weight of the door causes it to close from an open position or open from a closed position. They are not listed for use on fire doors.

Half Mortise. When one hinge flange or leaf is mortised into the butt edge of the door and the other to the surface of the frame.

Half Surface. When one hinge flange or leaf is fastened to the surface of the door and the other to the mortise cutout of the frame.

Single Acting. When a door swings in one direction only.

Spring Hinge. A hinge with flanges or leaves which attach to the door and jamb and are connected to the hinge pivot point(s) (barrel). Springs provide energy to close a door from the open position or, in some cases, open a door from the closed position. Single acting spring hinges are often listed for use on fire doors.

Spring Pivot Hinge. A spring hinge employing pivot points at the top and bottom edges of a door.

7.4.2 Builders' Hardware Terminology—Types of Locks

A Guide to Builders Hardware Terminology: ***Types of Locks***
(Covered in ANSI/BHMA Standards A156.2, A156.5, A156.12 and A156.13)

Auxiliary Lock. A lock having a latch bolt or a dead bolt operated by a key or a thumbturn or both. This lock is often used in addition to another lock, which may or may not be key operated but which has a latch bolt operated by knobs or levers.

Bored Dead Latch. (Also called tubular or cylindrical dead latch) A lock fitting round bored openings in the face and edge of a door and having a dead latch operated by a key or thumbturn or both.

Bored Dead Lack. (Also called cylindrical or tubular) These are locks or latches fitting round bored openings in the face and edge of a door. If they are key operated, the cylinder is contained in the knob and so occasionally one hears them referred to as "key-in-the-knob-locks." This is imprecise as other types of locks also have cylinders contained in the knobs. The round hole in the face of the door is usually 2 1/8 inches in diameter and the hole in the edge of the door is 7/8 inch to 1 inch. When the lock is installed, the face hole contains the lock body and the edge hole contains the latch bolt.

7.4.2 Builders' Hardware Terminology—Types of Locks (Continued)

Double Cylinder Dead Bolt. Any type of auxiliary lock requiring a key to project or retract the dead bolt (lock or unlock) from either side.

Interconnected Lock. (Also known by a number of different trade names) A lock having a separate latch and dead bolt mechanically interconnected and installed in round bored openings in the face and edge of a door. It is best known for providing dead bolt security with the life safety feature of simultaneous retraction. When the dead bolt is projected, a single turn of the inside knob retracts both the dead bolt and the latch bolt. This simultaneous retraction function is also available with some functions of mortise locks.

Mortise Dead Latch. An auxiliary lock fitting a cavity prepared in the edge of the door and having a dead latch operated by a key or thumbturn both. The key or thumbturn engages the lock through holes prepared in the faces of the door.

Mortise Dead Lock. An auxiliary lock having a deadbolt instead of a dead latch and otherwise the same as a mortise dead latch.

Mortise Lock. A lock fitting a rectangular shaped cavity in the edge of a door. A round hole in the face of the door receives a spindle to which knobs or levers are attached. If key operated, a second round hole above the first receives the cylinder(s) and thumbturn. Some functions use two cylinders which is not a violation of the codes because the inside knob always operates. Some functions use two cylinders which sometimes is a violation of codes because the inside key projects a dead bolt or locks the inside knob which can only be unlocked by key. (This example of key operation on the inside applies equally to other types of locks and is mentioned under mortise locks only because it originated with them.)

7.4.2.1 Lock Components

Backset. The distance from the edge of the door to the centerline of the cylinder at the centerline of the door thickness.

Bolts.

Auxiliary Dead Latch. A plunger which, when actuated, automatically locks a projected latch bolt against return by end pressure.

Dead Bolt. A lock component having an end which protrudes from or is withdrawn into, the lock front by action of the lock mechanism. When the door is closed and the dead bolt thrown, it extends into a hole provided in the strike thus locking the door. It does not retract with end pressure.

Latch Bolt. A lock component having a beveled end which projects from the lock front in an extended position, but may be forced back into the lock case by end pressure or drawn back by action of the lock mechanism. When the door is closed, the latch bolt projects into a hole provided in the strike thus holding the door in a closed position.

Deadlocking Latch Bolt. A spring actuated latch bolt with a beveled end and incorporating a plunger which, when depressed, automatically locks the projected latch bolt against return by end pressure. Also called dead latch.

Cam. In this publication, a component fastened to the back of a mortise cylinder plug or mortise cylinder thumbturn. When rotated, it engages the lock mechanism and either locks or unlocks.

Case. The housing of a lock.

Cylinder. The cylindrical subassembly of a lock containing a cylinder plug with keyway and a cylinder body with tumbler mechanisms.

Cylinder Body. The portion of a cylinder that surrounds the plug and contains the tumbler mechanism.

Cylinder Plug. A tubular portion of the cylinder which rotates within the cylinder body when the correct key is inserted into it and turned.

Cylinder Guard. Material that surrounds the otherwise exposed portion of a cylinder to protect the cylinder from wrenching, cutting, pulling, or prying.

Cylinder Housing. The portion of a lock that surrounds and retains the cylinder body. It can be a knob, part of the lock case or other anchoring means.

Lock Front. A plate fastened to the edge of a door through which the bolts pass.

Recessed Cylinder. A cylinder where the cylinder head is flush with, or recessed below, the outside surface of the trim to protect the cylinder from wrenching, cutting, pulling or prying.

Strike. A plate fastened to the door frame or the inactive leaf of a pair of doors into which the bolts project.

Armored Strike. A strike reinforced in such a way as to strengthen the frame to which it is applied.

Strike Box. A housing used in back of a strike to enclose the bolt openings.

Tailpiece. A bar projecting from the back of a rim or bored lock cylinder engaging the lock mechanism and when rotated by the key or thumbturn either locks or unlocks.

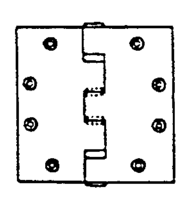
Thumbturn. The component that projects or retracts a dead bolt or latch bolt by grasping with the thumb and fingers and turning. Sometimes called a turnpiece or turn.

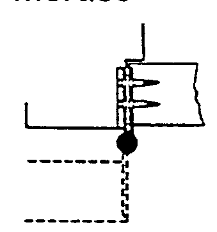
Finish hardware selections and specifications span a wide range of functions, materials of construction and decorative requirements. The information contained in this section touches on hardware mainstays: locksets, latchsets with trim and cylinders, hinges (butts), panic devices, and informative specification tables. Although much of this information was furnished by two manufacturers, it remains very much generic in nature.

7.4.3 Half and Full Mortise and Surface Hinges Illustrated

The butts are available in a wide range of metals.

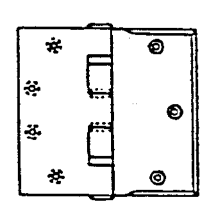
Full Mortise

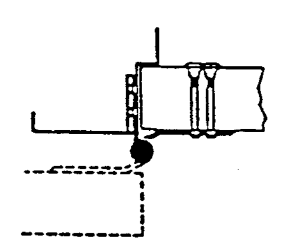




These butts have two equal square-edged leaves; one is mortised into the door and the other into the frame. It is available in standard, heavy, or extra heavy weight.

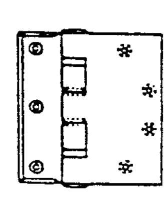
Half Surface

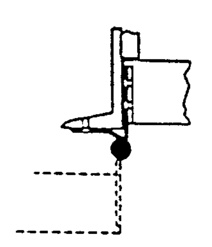




These butts have two equal leaves; one is square-edged and the other is bevel-edged; the square edge is mortised into the frame, the bevel edge is surface mounted on the door. It is available in standard and heavy weight.

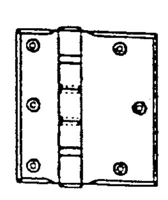
Half Mortise

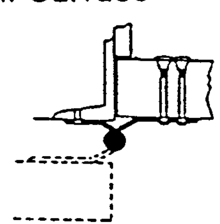




These butts have two equal leaves; one is square edged and the other is bevel edged; the square edge is mortised into the door edge and the bevel edge is mounted on the frame. It is available in standard and heavy weight.

Full Surface



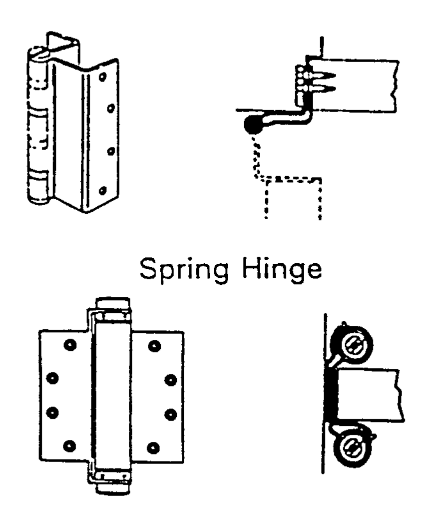


Two bevel-edged leave butts are of unequal size; one is mounted on the frame, the other on the door.

7.4.4 Special Butt, Spring, Pivot, and Invisible Hinges Illustrated

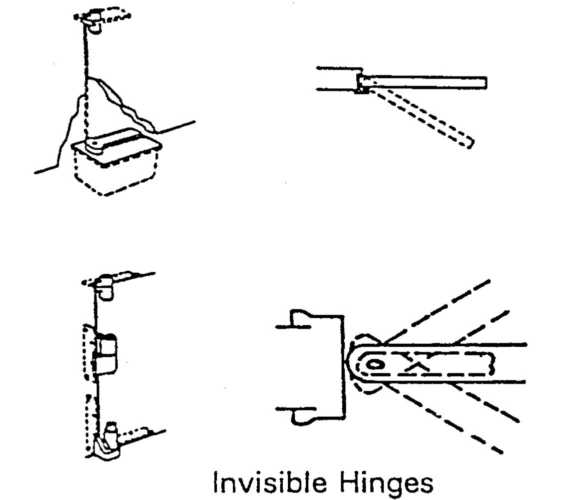
All of the above butts are generally available in sizes referring to their height: 4½" (11.43 cm), 5" (12.7 cm), and 6" (15.24 cm).

Special Butts



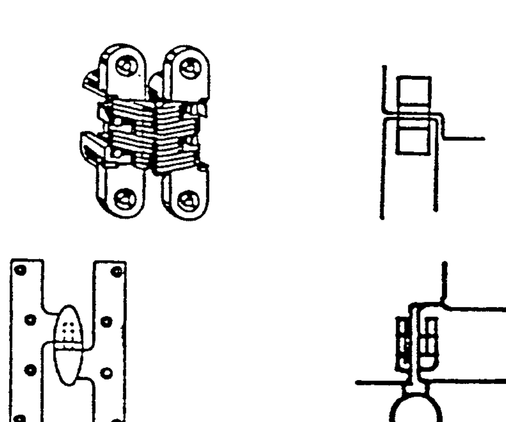
Swing clear/full mortise are also available in half-surface, half-mortise, and full-surface configurations. These types of butts provide an unobstructed clear frame opening when door is in the 90° open position. It is available in either a single- or double-acting configuration, usually mortised into the door and frame, providing closing action without a separate closer.



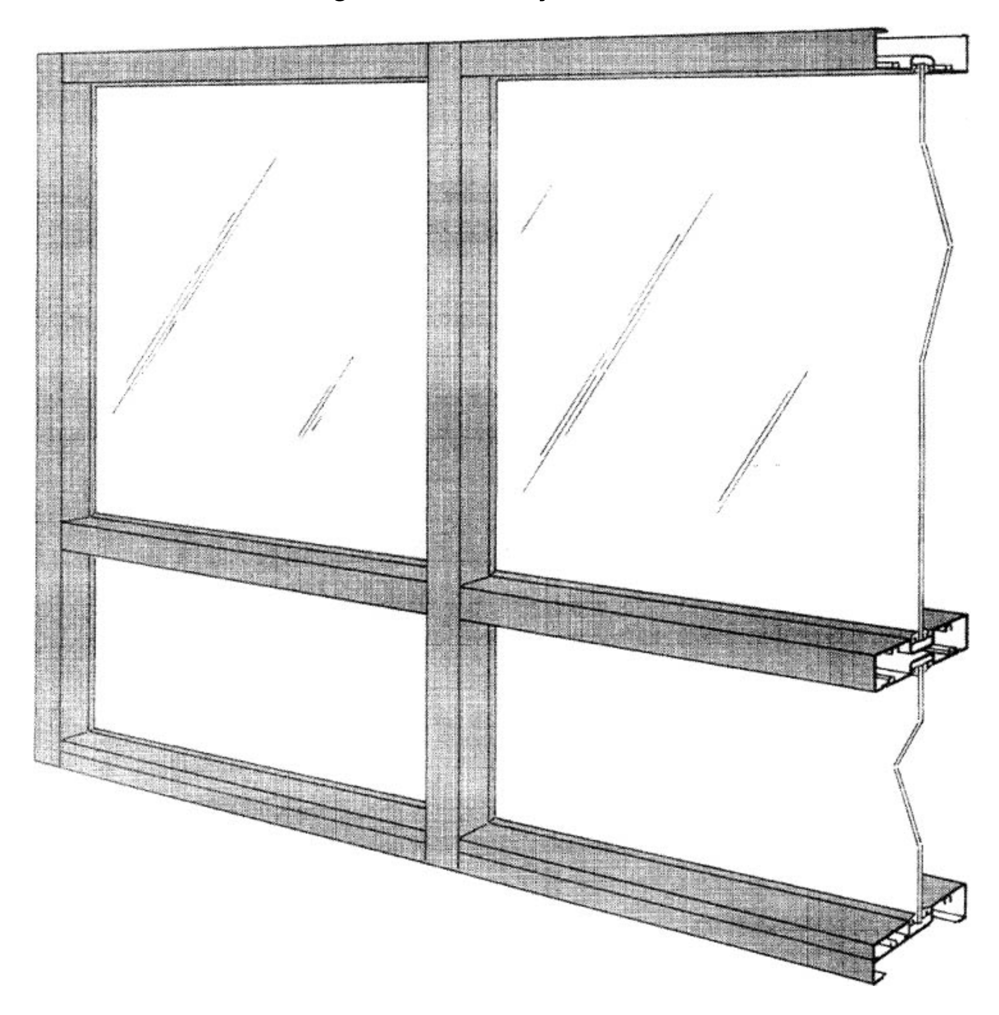


Offset pivot hinges are mortised into the top and bottom edges of the door and into the frame jamb at the top and bottom. These hinges can also be mortised into the floor and the top of the frame. Center pivot hinges are attached to the top and bottom edges of the door and either into the top and bottom of the frame or into the floor and the top of the frame. Fully mortised into the edge of the door and frame, the hinge portion is not visible when the door is closed, except when the Paumelle or Olive Knuckle hinge is used, the olive-shaped portion is visible as an architectural feature.

Invisible Hinges



7.5.0 Aluminum Storefront Framing and Window System



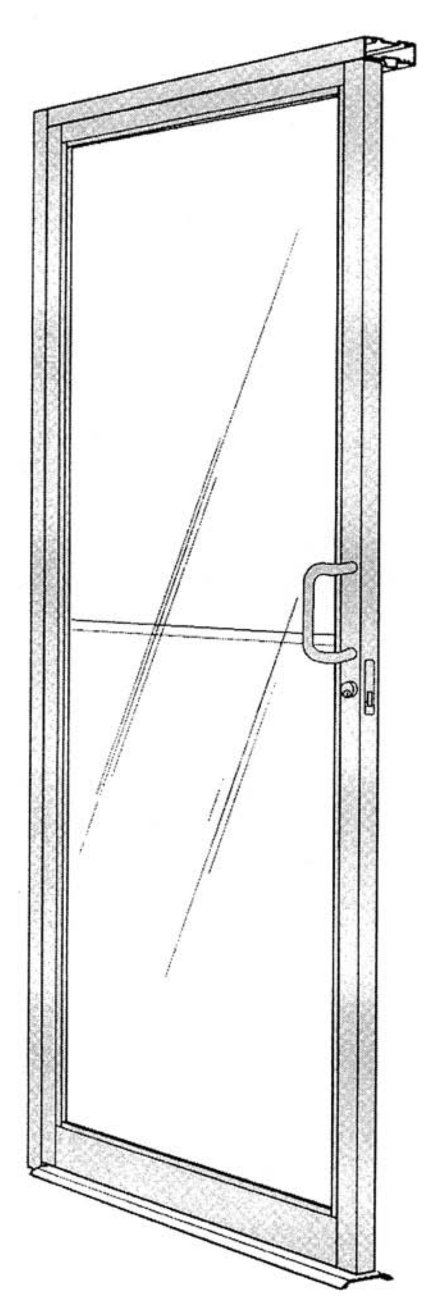
Description

Tubelite® 4500 Series Framing is a 1¾" x 4½" flush glazed fixed window system. Infill material up to ⅜" thick is glazed in the center of the frame with roll-in gaskets, and weeped through the vertical members. 4500 Series is recommended for first floor storefront applications and is compatible with most Tubelite® entrance systems.

By permission, Tubelite Inc., Walker, MI.

7.5.1 Standard Aluminum and Glass Entrance Doors

Standard Entrances
Description



Description

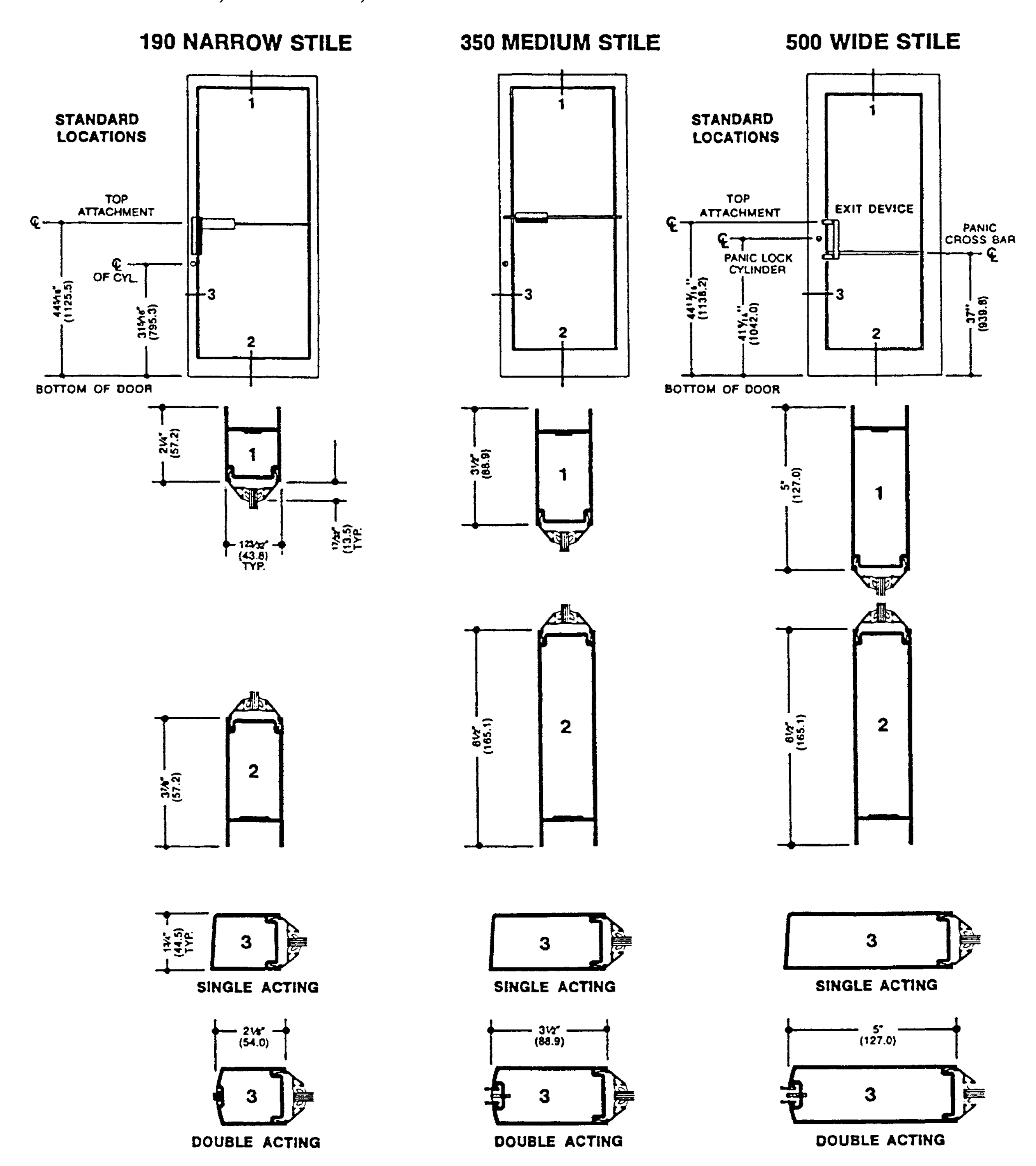
Tubelite Standard Entrances have an outstanding reputation for craftsmanship and strength. The Narrow Stile Door has a face dimension of 2 1/8" and is designed for average commercial use. Medium Stile (4") and Wide Stile (5") Doors provide extra durability for heavier usage and a greater variety of hardware options. Optional bottom rail heights of 7 1/2" and 10" are available for accessibility requirements. Snap-in glass stops provide for 1/4" or 1" glazing thicknesses.

Standard Entrances are furnished with mortised butt hinges, offset pivots or center pivots as specified. Standard deadbolt locks, concealed vertical rod or rim panic exit devices may also be selected. Standard pull handles have been designed for ADA access and have matching push bars.

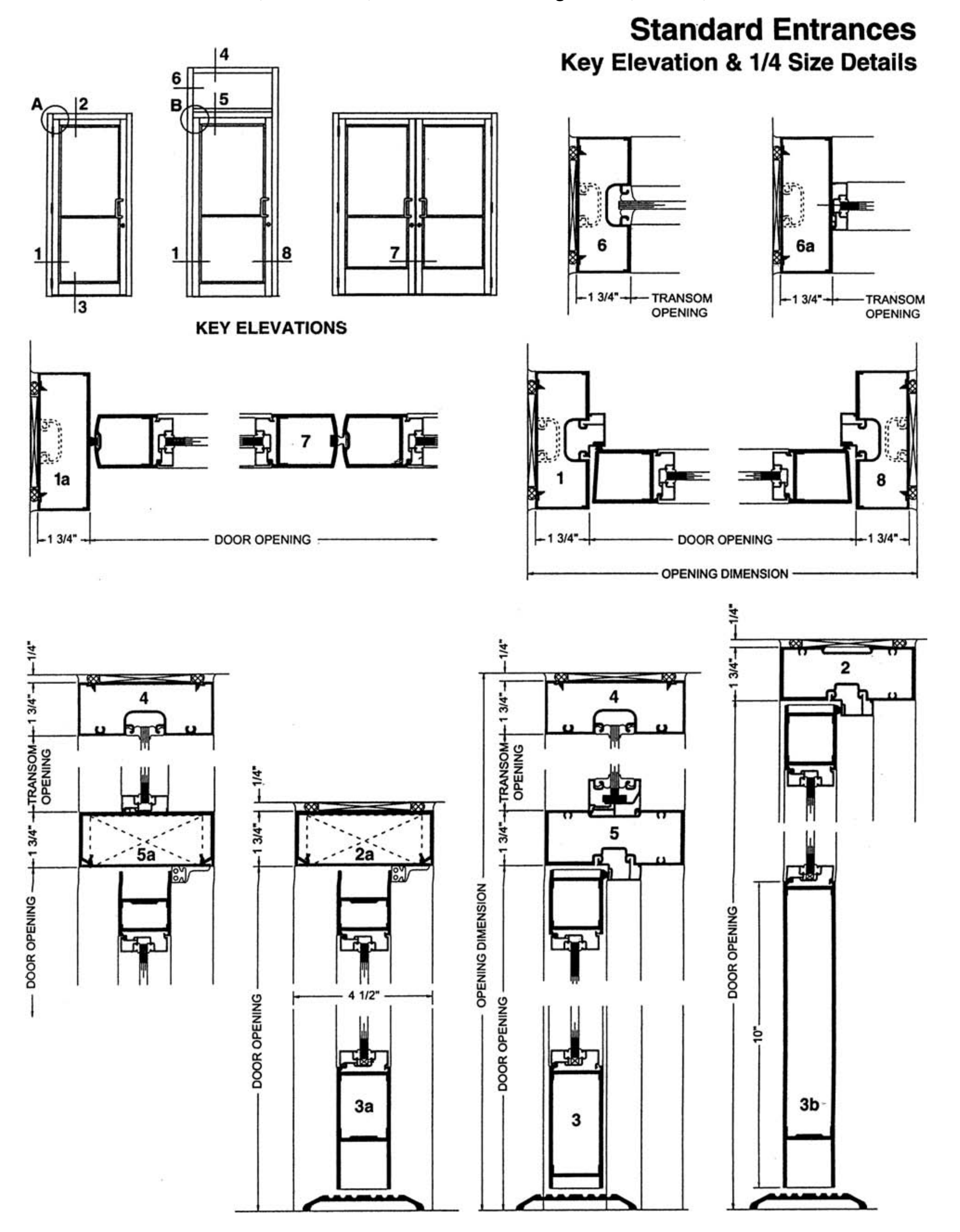
The standard door frame has snap-in door stops to conceal frame anchors and provide an excellent weatherseal. Open-back vertical door jambs allow easy, fast assembly with the screw-spline head member. Snap-in vertical frame closures easily accommodate addition of sidelights and incorporation

By permission, Tubelite Inc., Walker, MI.

7.5.1.1 Narrow-Stile, Medium-Stile, and Wide-Stile Doors

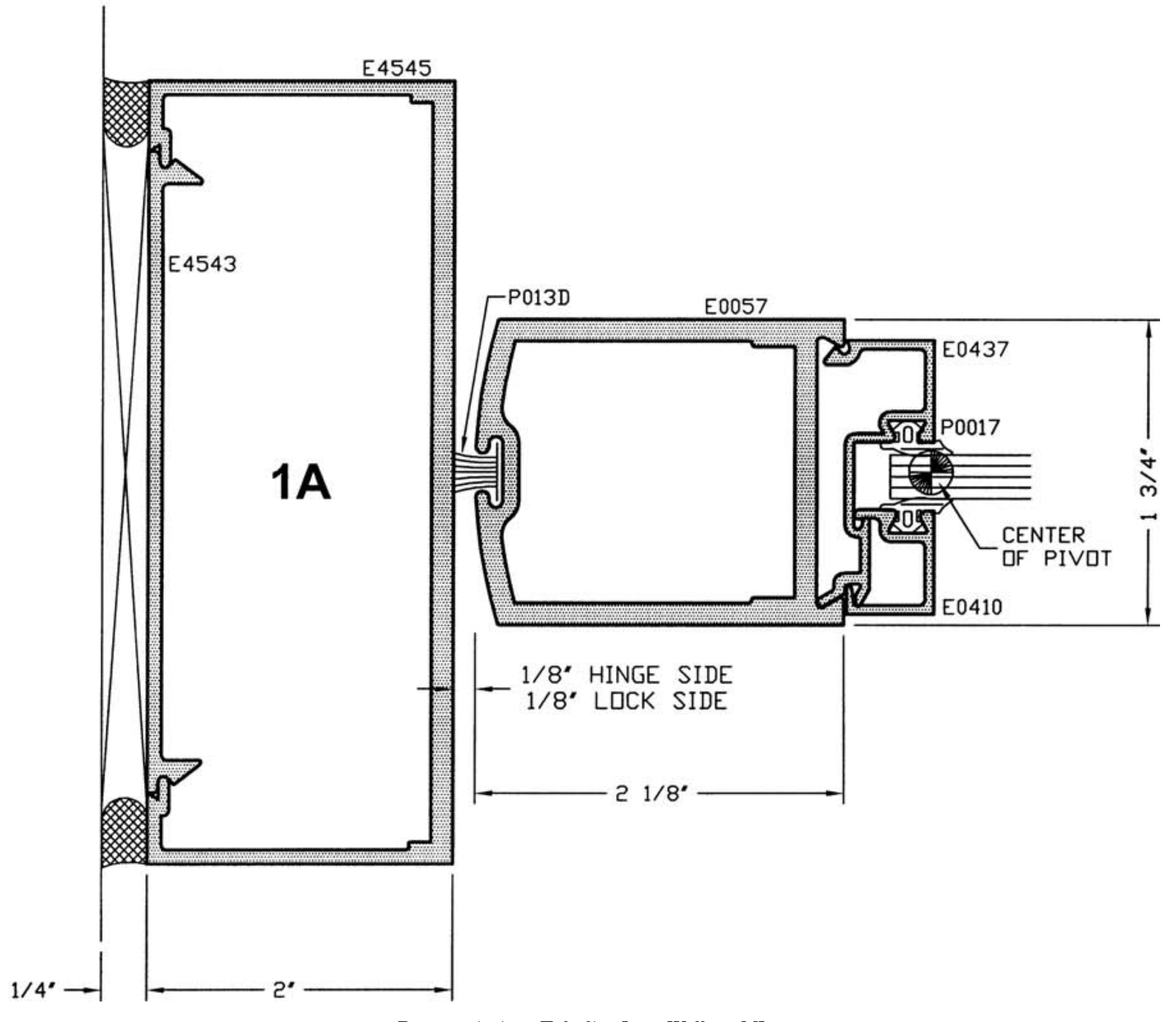


7.5.2 Standard Entrances, Elevations, and Sections through Head, Jambs, and Sill



By permission, Tubelite Inc., Walker, MI.

7.5.3 Section through Jamb of Center Pivot Door



By permission, Tubelite Inc., Walker, MI.

7.5.3.1 Section through a Narrow-Stile Jamb with a Continuous Hinge

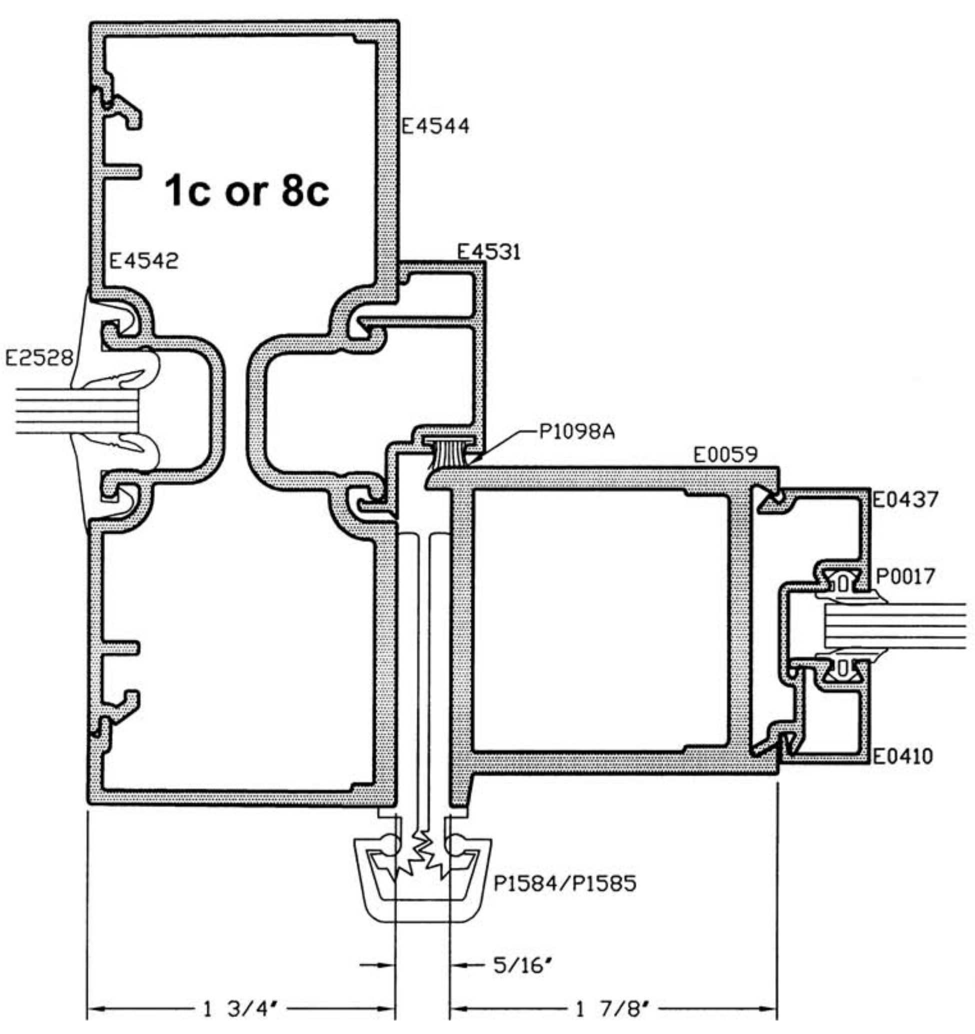
Standard Entrances

4500 Door Jamb - Narrow Stile With Continuous Hinge

CAD DETAIL FILE NO.
160DRJBNSCH

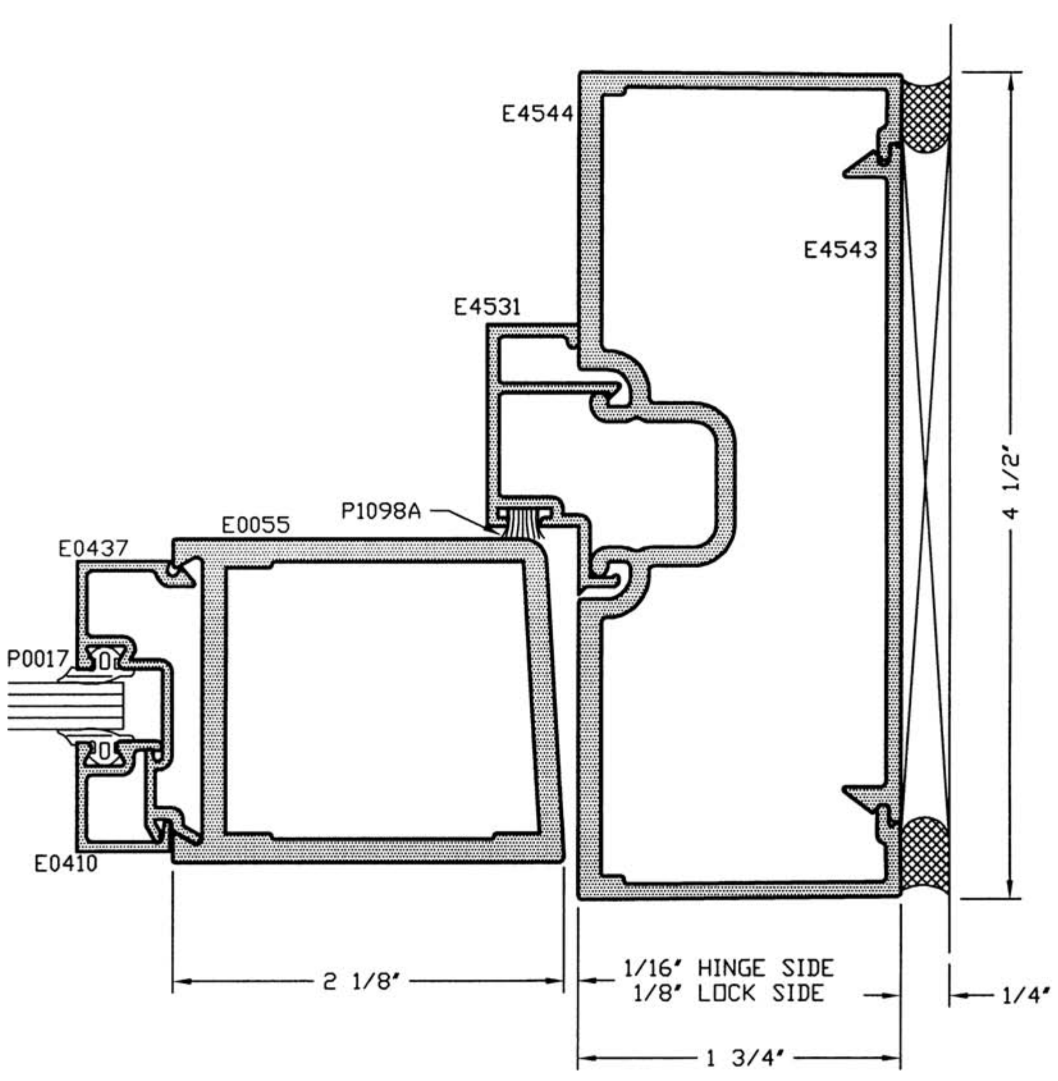
STANDARD SIZES

SINGLE DOORS	DOUBLE DOORS
3'-0" X 7'-0"	5'-0" X 7'-0"
3'-6" x 7'-0"	6'-0" x 7'-0"



By permission, Tubelite Inc., Walker, MI.

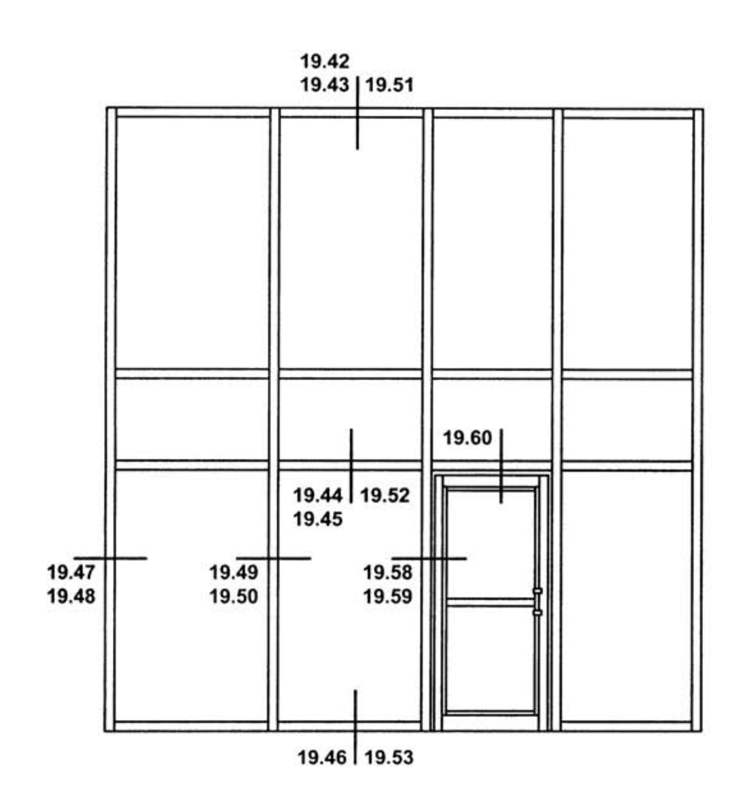
7.5.3.2 Section through Medium-Stile Jamb and a Pivot or Butt Hinge Installation

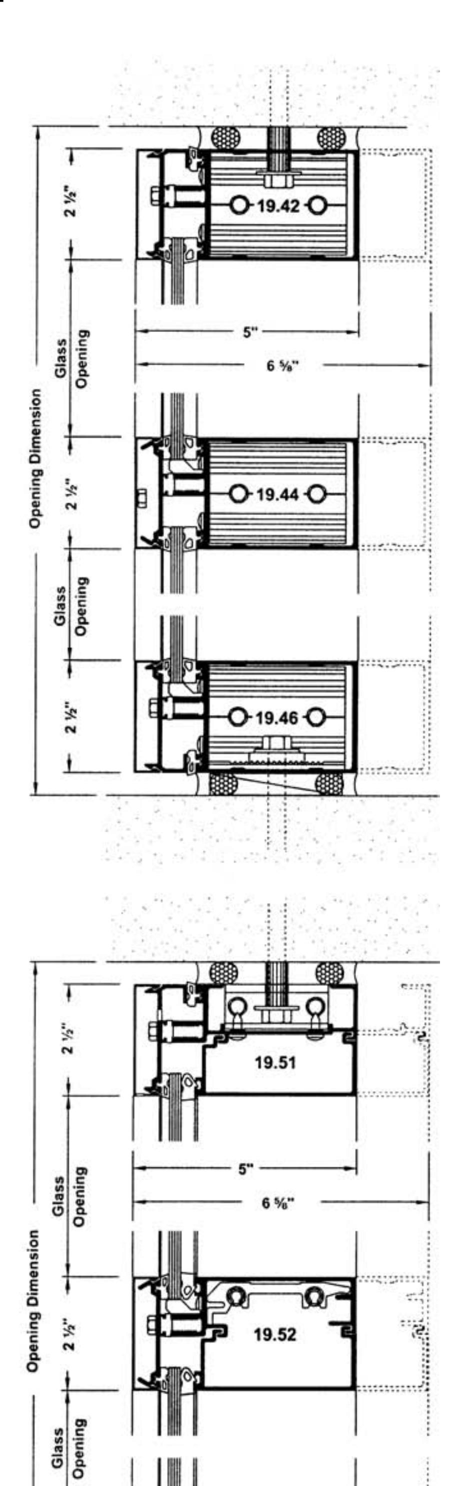


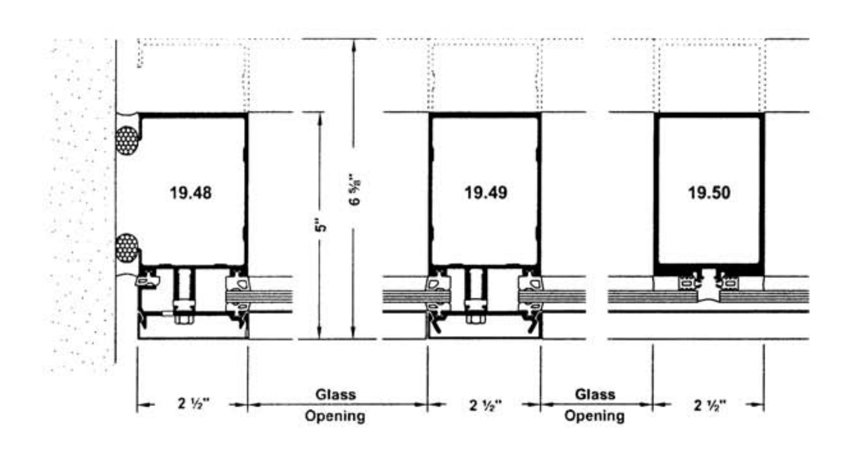
By permission, Tubelite Inc., Walker, MI.

7.6.0 Elevation of a Typical Storefront and Curtain Wall Installation

400 I.G. Series Curtainwall
1/4 Size Details

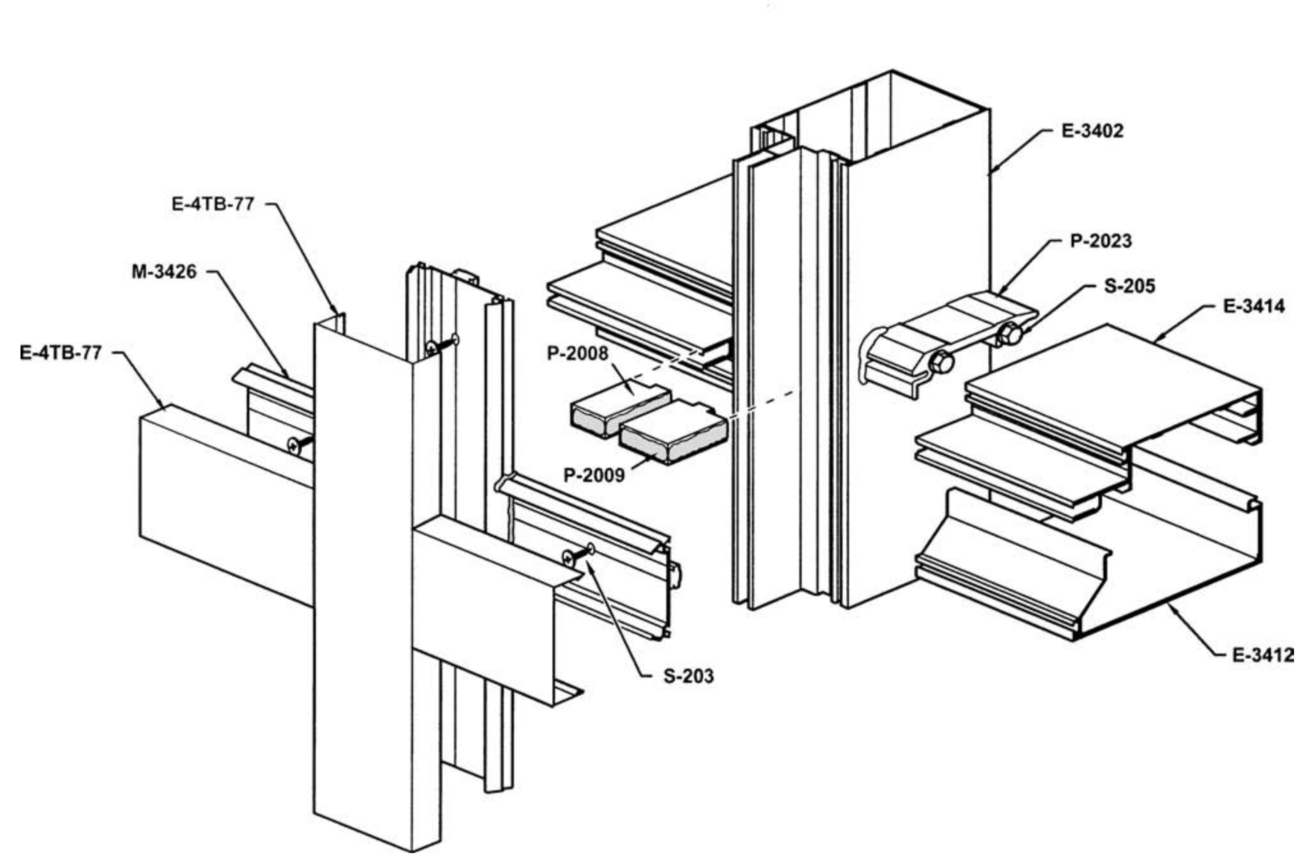






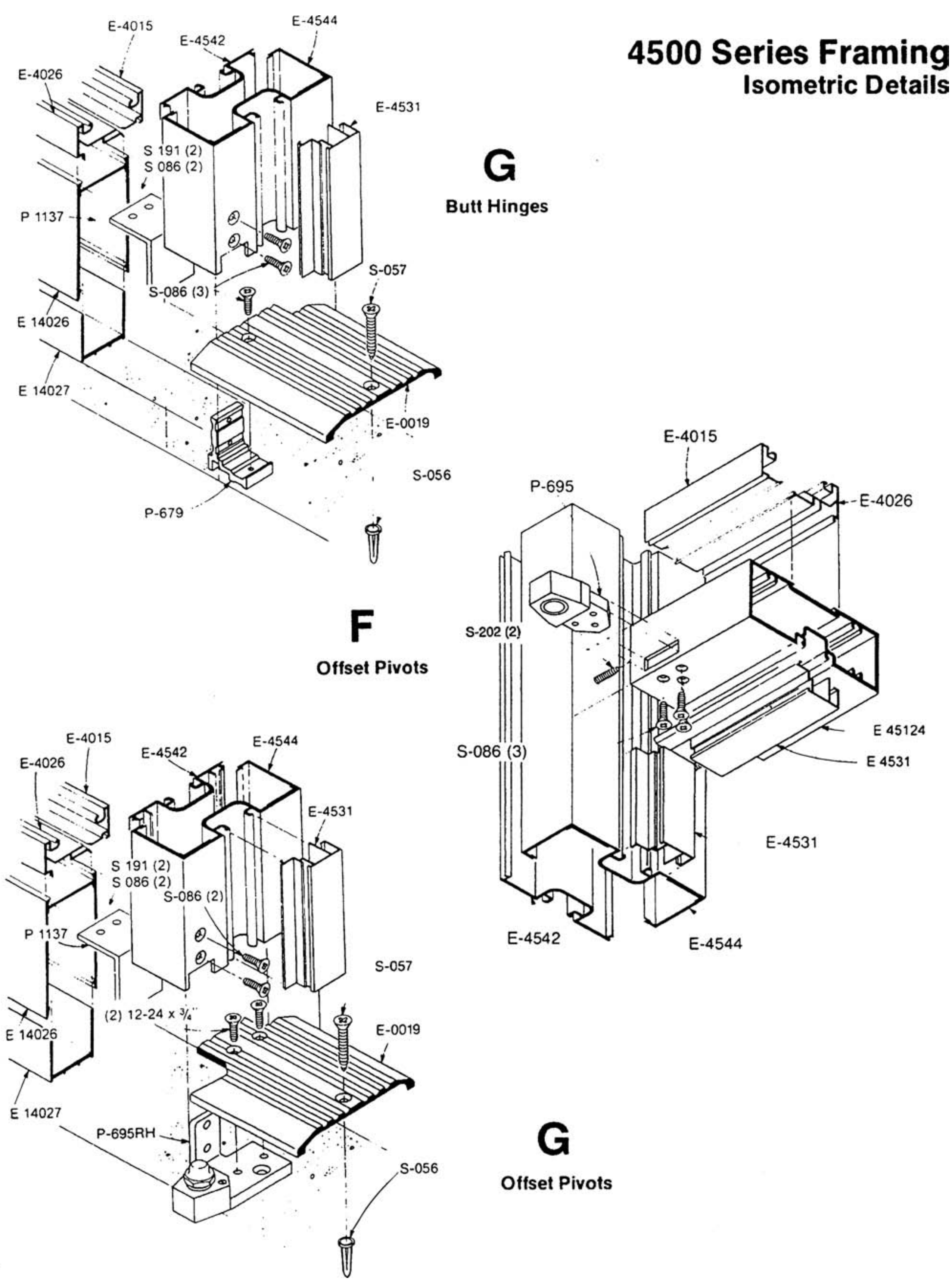
By permission, Tubelite Inc., Walker, MI.

7.6.1 Isometric of Curtain Wall Construction Details



By permission, Tubelite Inc., Walker, MI.

7.6.2 Isometric of Curtain Wall Construction—Hinge and Sill Installation Details



By permission, Tubelite Inc., Walker, MI.

7.7.0 Windows—Aluminum, Wood, Steel, and Plastic

Aluminum Windows

According to ANSI/AAMA-101, aluminum used in the manufacture of windows must meet the following specifications:

- *Yield strength* 16,000 psi (110.24 MPa)
- *Tensile strength* 22,000 psi (151.6 MPa)
- *Coefficient of thermal expansion* 13 × 10 to the 6-inch/(2.45 cm) degree Fahrenheit (to convert F to C, subtract 32 and divide by 1.8)

Aluminum windows are susceptible to corrosion if their painted or anodized surfaces are exposed to the environment. Unless airborne contaminants are removed periodically by washing, they will attract and hold moisture. In combination with pollutants, over time, the exposed painted or anodized metal surface will be attached.

Aluminum is an excellent heat and cold transmitter. Without a thermal break in the window frame, it will always present a cold interior surface during winter months. Aluminum window components tend to expand and contract rapidly in response to temperature changes, causing stresses on improperly installed glazing. If these stresses become excessive, cracks will develop in the glazed section. However, aluminum windows are very cost-effective; are manufactured in a wide range of sizes, configurations, and colors; and are generally maintenance-free, compared to wood windows.

Steel Windows

These windows are usually constructed of hot-rolled, #12 steel and are classified by the minimum combined weight of the outside frame and vent member.

- *Residential grade* Minimum 2.0 pounds (0.9 kilogram) with maximum 1 inch (2.54 cm) from front to back. The maximum dimension is 6½ feet (1.98 meters) and the maximum spacing of mullions is 3½ feet (1.07 meters).
- *Standard grade* Minimum 3.0 pounds per lineal foot (1.36 kilograms per 30.48 cm) with a maximum of 1¼ inches (3.17 cm) front to back, ¾ inch (1.9 cm) vertical muntin required in projected vents over 4½ feet (1.37 meters) wide. The maximum glazed area is 60 square feet (5.58 square meters) and a maximum dimension is 10 feet (3.05 meters). For combined units, a maximum mullion spacing of 6½ feet (1.98 meters) is permitted.
- *Heavy intermediate grade* Minimum of 3.5 pounds per lineal foot (1.58 kilograms per 30.48 cm) with a maximum of 1⁵⁄₁₆ inches (3.33 cm) from front to back, ¾ inches (1.90 cm) vertical muntin in projected vents over 5 feet (1.52 meters). The maximum glazed area is 84 square feet (7.8 square meters). For combined units, a maximum spacing of mullions is 6½ feet (1.98 meters).
- *Heavy custom grade* Minimum 4.2 pounds per lineal foot (1.91 kilograms per 30.48 cm) with a maximum of 1½ inches (3.8 cm) from front to back of the ventilator and the supporting frame.

Steel windows exhibit great strength, allowing for large glazed areas. Thermal expansion is minimal, but thermal breaks in the frames are required to prevent the transmission of heat and cold from exterior to interior areas. These windows require periodic maintenance to ensure the integrity of their protective coatings to prevent rusting of their components.

Plastic/Vinyl Widows

Vinyl windows are manufactured to ASTM D4216 specifications that require the minimum properties of the polyvinylchloride (PVC) to have an impact resistance of 0.65 four pounds per inch (0.045 kilograms per square centimeter) of notch, a tensile strength of 5000 psi (34.5 Mpa), a modulus of elasticity in tension of 0.29×10^6, deflection temperature under load at 140 degrees F (77°C) and a coefficient of expansion of less than 2.2 × 10 to the minus 5th inch (2.54 cm)/inch (2.54 cm)/degree Fahrenheit (to convert F to C, subtract 32 and divide by 1.8).

Vinyl windows can be manufactured in many textures and colors, including wood-finish look-alikes. Although stabilizers are added to the vinyl compound, some dark colors have been known to

fade or distort when exposed to strong sunlight for extended periods of time. Vinyl windows are difficult to refinish if damaged or if the color fades. Vinyl windows exhibit excellent thermal properties, do not expand or contract to any noticeable degree when subjected to heat or cold and are relatively maintenance-free and cost-effective.

Wood Windows

Wood windows offer beauty and warmth, as well as exhibiting excellent thermal qualities. Protection from the elements and condensation requires that both interior and exterior surfaces are either painted or otherwise sealed to prevent wood rot. Several manufacturers offer aluminum or vinyl cladding to minimize exterior maintenance.

7.7.1 Architectural Glass Categorized

Architectural glass falls into one of four types: annealed, heat-strengthened, fully tempered, and laminated.

- *Annealed.* This is the most common form of architectural glass. Not being heat-treated, this type of glass is not subject to the distortion associated with the tempering process. It has good surface flatness, but its major disadvantage is that it breaks into sharp, dangerous shards when subjected to impact.
- *Heat-strengthened*. This type of glass is heat-strengthened and fully tempered. It has twice the strength of annealed glass with respect to resistance to breakage from wind load or thermal shock. Although the heat treatment does result in some minor distortions when compared to annealed glass, like the annealed product, it does break into large shards.
- *Fully tempered*. This product provides at least 4 times the strength of annealed glass, giving it superior resistance to breakage. Although it provides some distortion, its advantage, other than strength, lies in its ability to break into small fragments when shattered.
- *Laminated.* Laminated glass is composed of two or more lights held together with a plastic interlayer that prevents the fallout of dangerous shards when the light is fractured.

7.7.2 Window Glazing Options

The window glazing options include clear, tinted, spectrally selective, and reflective, each of which satisfies different design and performance requirements.

- *Clear glazing*. Glass without any tint or coating to lower its visibility or energy performance qualifies as “clear” glazing.
- *Tinted glazing*. Often referred to as heat-absorbing glass, these tinted glazing panels block solar heat by absorbing it into the glass itself, causing the temperature of the glass to rise as a result. Common tints are bronze, gray, and green, all of which seem to absorb heat at the same proportion. Black tint, however, absorbs much more visible energy than heat energy and therefore presents the worst cooling load reduction.
- *Spectrally selective glazing*. These coatings are designed to admit a higher level of visible light while controlling solar heat. The popular low-emissivity or “low-*E*” glazings are spectrally selective glazed coatings that provide better insulation value, good visibility characteristics, and good solar control.
- *Reflective glazing*. These semitransparent metallic coatings are applied to either clear or tinted glass and provide a high degree of solar heat control due to their reflective nature. Although they reduce cooling loads, they do so at the expense of daylight transmittance, and when installed on buildings in close proximity to one another, they can transmit their reflected solar heat to those nearby buildings.

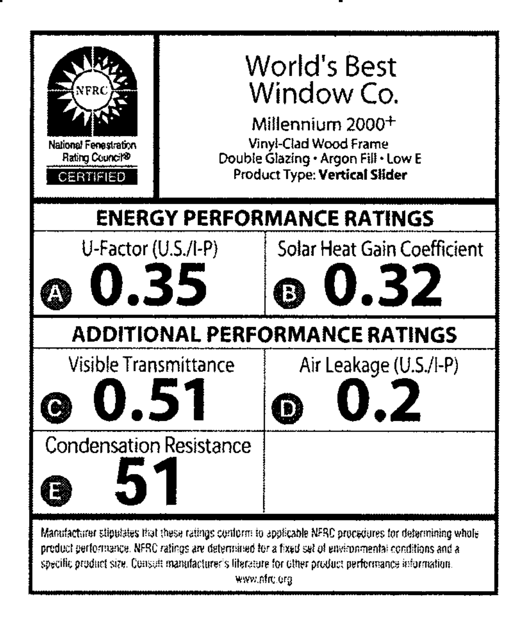
7.7.3 Window Performance Ratings

Three types of labels can be affixed to windows: AAMA, NWWDA, and NAMI.

- *AAMA*. The American Architectural Manufacturers Association certifies that the design and fabrication of the window have met the requirements as specified on the label.

- *NWWDA*. The National Wood Window and Door Association covers only wood windows and doors, and its primary function is to develop industry standards and certification programs for wood windows, doors, and skylights.
- *NAMI.* The National Accreditation and Management Institute is an independent organization that provides third-party certification and inspection services for the fenestration industry. NAMI works in conjunction with two government agencies, the Department of Housing and Urban Development (HUD) and the American National Standards Institute (ANSI), to create national standards for the industry.

7.7.3.1 Sample Window Sticker and Explanation of Energy and Performance Ratings



A ***U-Factor*** *measures how well a product prevents heat from escaping a home or building. U-Factor ratings generally fall between 0.20 and 1.20. The lower the U-Factor, the better a product is at keeping heat in. U-Factor is particularly important during the winter heating season. This label displays U-Factor in U.S. units. Labels on products sold in markets outside the United States may display U-Factor in metric units.*

B ***Solar Heat Gain Coefficient*** *(SHGC) measures how well a product blocks heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking unwanted heat gain. Blocking solar heat gain is particularly important during the summer cooling season.*

C ***Visible Transmittance*** *(VT) measures how much light comes through a product. VT is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.*

D ***Air Leakage*** *(AL) measures how much outside air comes into a home or building through a product. AL rates typically fall in a range between 0.1 and 0.3. The lower the AL, the better a product is at keeping air out. AL is an optional rating, and manufacturers can choose not to include it on their labels. This label displays AL in U.S. units. Labels on products sold in markets outside the United States may display AL in metric units.*

E ***Condensation Resistance*** *(CR) measures how well a product resists the formation of condensation. CR is expressed as a number between 1 and 100. The higher the number, the better a product is able to resist condensation. CR is an optional rating, and manufacturers can choose not to include it on their NFRC labels.*

Source: National Fenestration Rating Council (NFRC).

7.7.4 Window Performance Ratings Related to Energy Efficiency

- *U value*. This is the rate of heat flow through a window *assembly* due to the temperature difference between the outside and inside of the window. The lower the *U* value, the greater the insulating quality of the window.
- *Shading coefficient (SC).* This rating relates to the ability of the glazed area to block the sun's radiant heat. The shading coefficient is the relation of the solar heat gain of a window compared to a single pane of ½-in. clear glass, The lower the SC, the lower the solar heat gain.
- *Solar heat gain coefficient (SHGC).* This measure relates to the amount of solar radiation passing through a window as heat compared to the amount of solar radiation striking the outer surface of the window. This measure has become a standard performance factor by more and more window manufacturers. The lower the SHGC, the lower the solar heat gain.
- *Visible light transmittance (VLT).* Pertaining to the percentage of light passing through a window, a high VLT indicates a greater fraction of incident natural light is passing through the window. VLT considerations need to be taken into account when SC and SHGC ratings are also being considered.
- *Ultraviolet transmittance*. Many energy-efficient glazing coatings also reduce uv transmission.
- *Sound transmission*. Expressed as outdoor-to-indoor transmission class (OITC), these ratings reflect sound insulation properties. The higher the OITC, the better the window's sound absorption qualities.

7.7.5 Typical Window Performance Values

Typical Window Performance Values

Glazing Type	U-Value Of Glazing	Shading Coefficient	Solar Heat Gain Coefficient	Visible Light Transmittance
Single-pane, clear	0.88	1.00	0.86	90%
Double–pane, clear	0.48	0.87	0.75	81%
Double – pane, clear, low-e	0.32	0.70	0.60	73%
Double–pane, tinted (bronze)	0.48	0.59	0.50	48%
Double – pane, tinted (green), low-e	0.32	0.48	0.42	61%
Double–pane, reflective	0.48	0.26	0.22	18%

Source: WaysToSave/BusWays.com.

7.7.5.1 Values Based on Testing of Various Coatings on Residential Windows

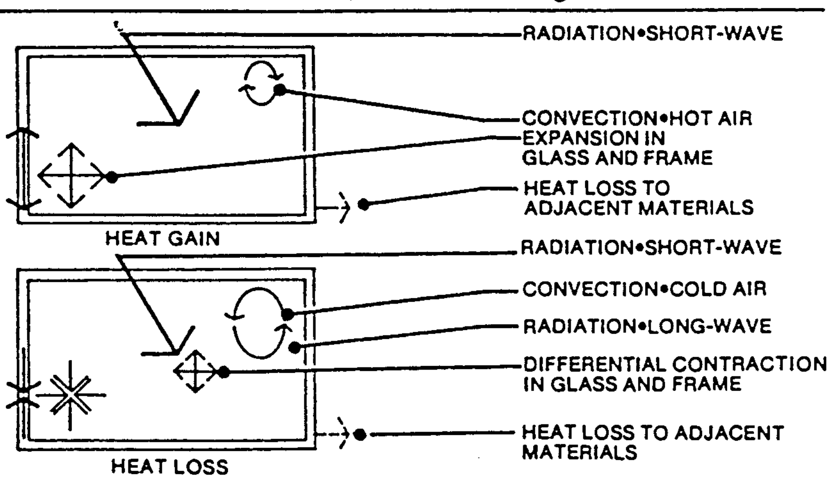
Values based on results from Architectural Testing - residential

Tint	Components	Description	U-Value[1]	SHGC[2]	VT[3]
clr/clr	clear/clear 1 lite	1/8" clr + 3/8" spacer + 1/8" clr	0.45	0.42	0.43
clr/clr		3/16" clr + 1/4" spacer + 3/16" clr	0.47	0.42	0.43
clr/clr	clear/clear TDL	1/8" clr + 3/8" spacer + 1/8" clr	0.47	0.35	0.34
clr/clr		3/16" clr + 1/4" spacer + 3/16" clr	0.49	0.35	0.34
clr/Low E	PPG Sungate 500/Low E/clr 1 lite	1/8" clr Low E + 3/8" spacer + 1/8" clr	0.39	0.37	0.40
clr/Low E	PPG Sungate 500 Low E/clr 1 lite	3/16" clr Low E + 1/4" spacer + 3/16" clr	0.42	0.37	0.40
clr/Low E	PPG Sungate 500 Low E/clr TDL	1/8" clr Low E + 3/8" spacer + 1/8" clr	0.42	0.31	0.32
clr/Low E	PPG Sungate 500 Low E/clr TDL	3/16" clr Low E + 1/4" spacer + 3/16" clr	0.45	0.31	0.32
clr/Low E	Solar Ban 60 Low E/clr 1 lite	1/8" sbclr Low E + 3/8" spacer + 1/8" clr	0.36	0.23	0.37
clr/Low E	Solar Ban 60 Low E/clr TDL	1/8" sbclr Low E + 3/8" spacer +	0.40	0.20	0.30

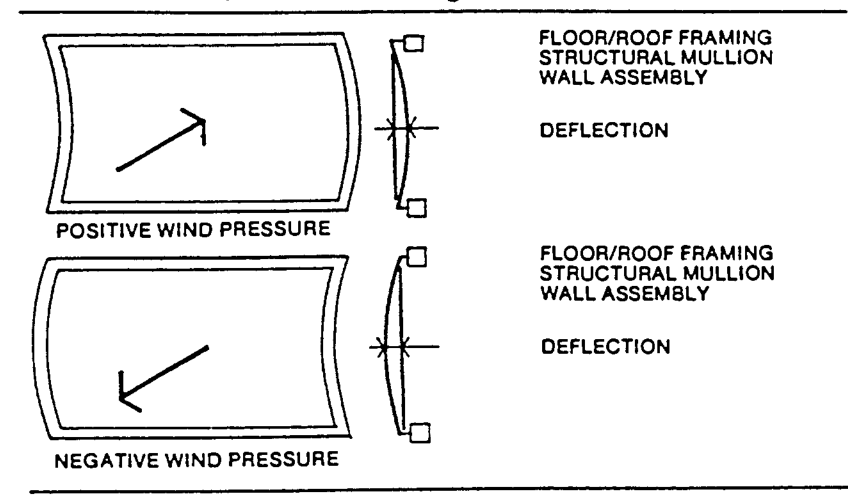
Source: National Fenestration Rating Council and National Wood Window and Door Manufacturers Association.

7.8.0 Thermal Movement of a Window Frame and Glass

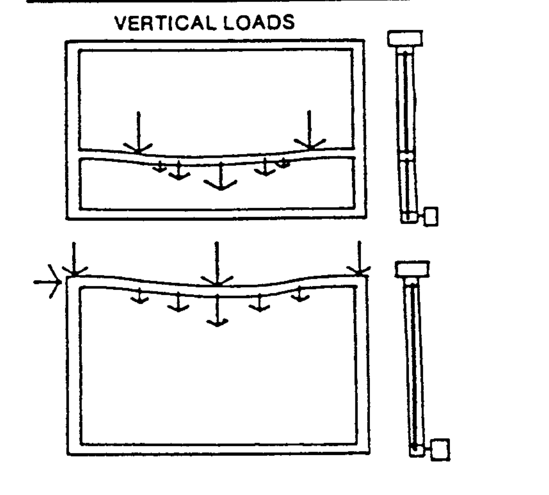
THERMAL MOVEMENT, in frame and glass



DEFLECTION, vertical framing members



DEFLECTION, horizontal framing members



DEFLECTION IN LINTEL
DEFLECTION IN MULLION
EXCESSIVE DEFLECTION MAY
IMPOSE STRESS ON GLASS

TWIST IN MULLION DUE
TO VERTICAL OR LATERAL
LOADS•MAY RESULT IN
LATERAL PRESSURE ON GLASS

DEFLECTION IN MULLION
DUE TO WEIGHT OF GLASS
MAY IMPOSE STRESSES ON
GLASS IN LOWER FRAME

Section

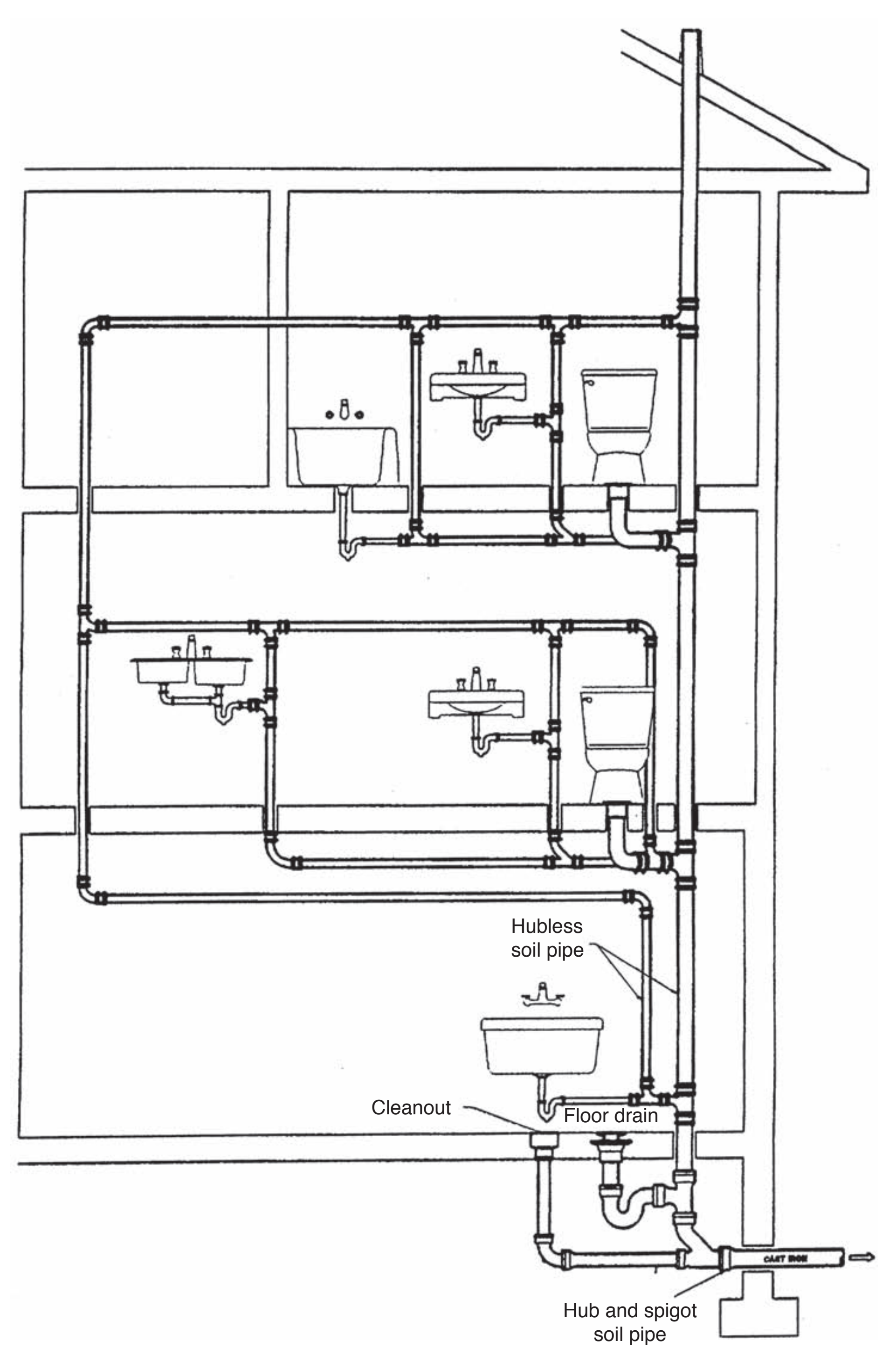
8

Plumbing

Contents

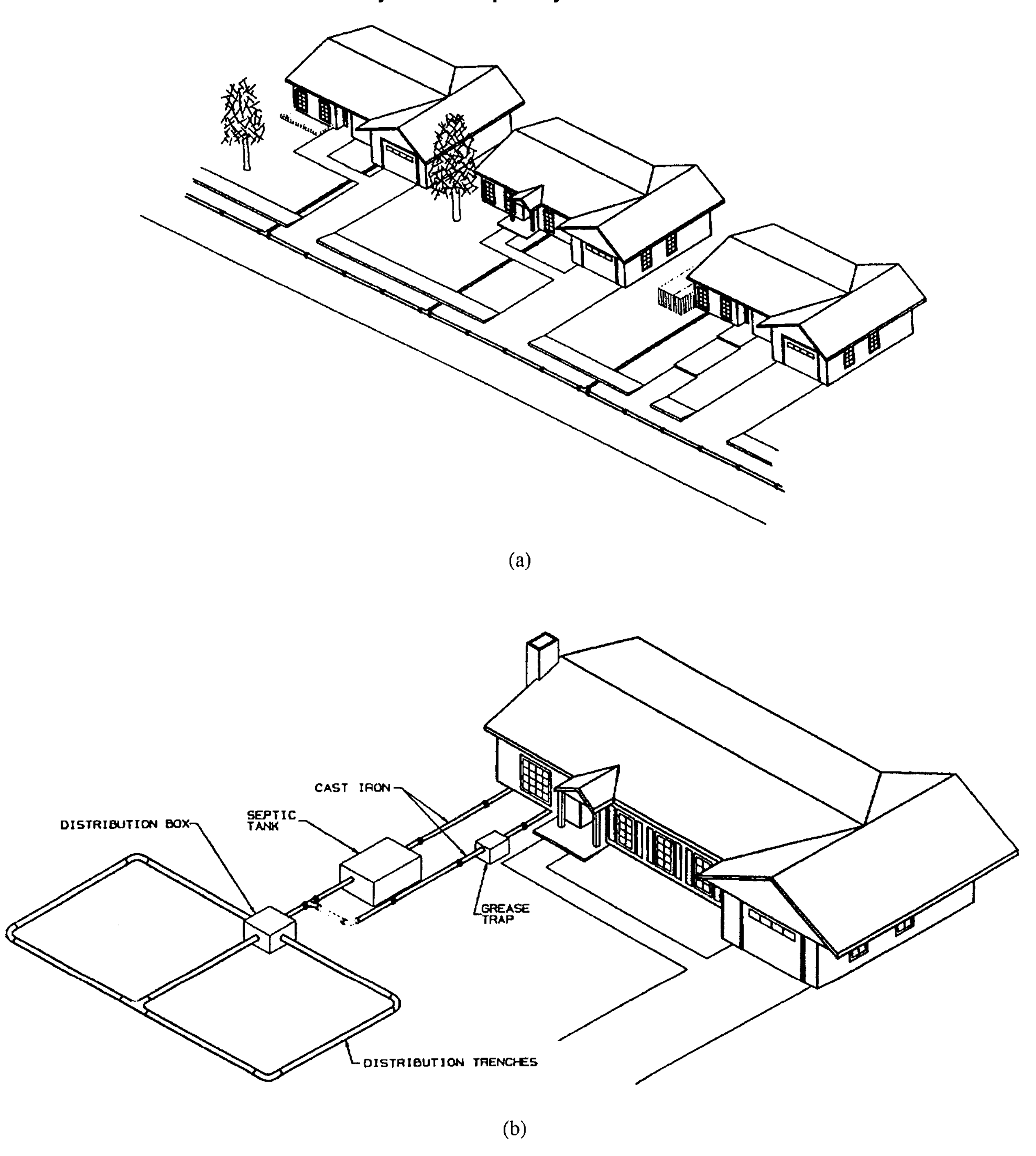
8.0.0 Typical Plumbing Waste/Vent Layouts

This is a multistory, hubless and hub and spigot piping system.



By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

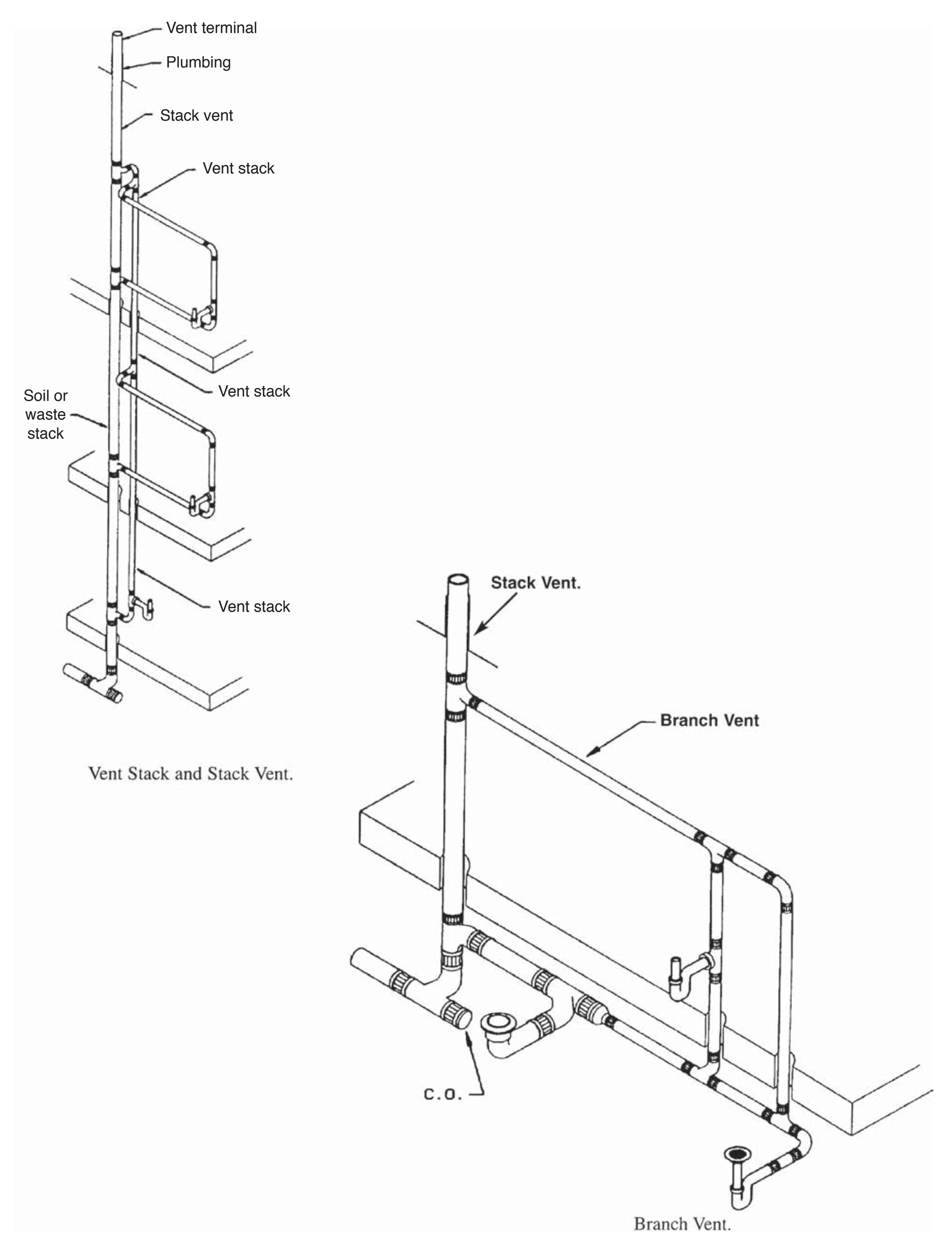
8.0.1 Residential Waste Lines to City Sewer/Septic Systems



Typical Piping Layouts and Details for Septic Tank Use: (a) Houses Connected to a Municipal Sewer System; (b) House Connected to a Septic Tank System.

By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.0.2 Vent Stacks

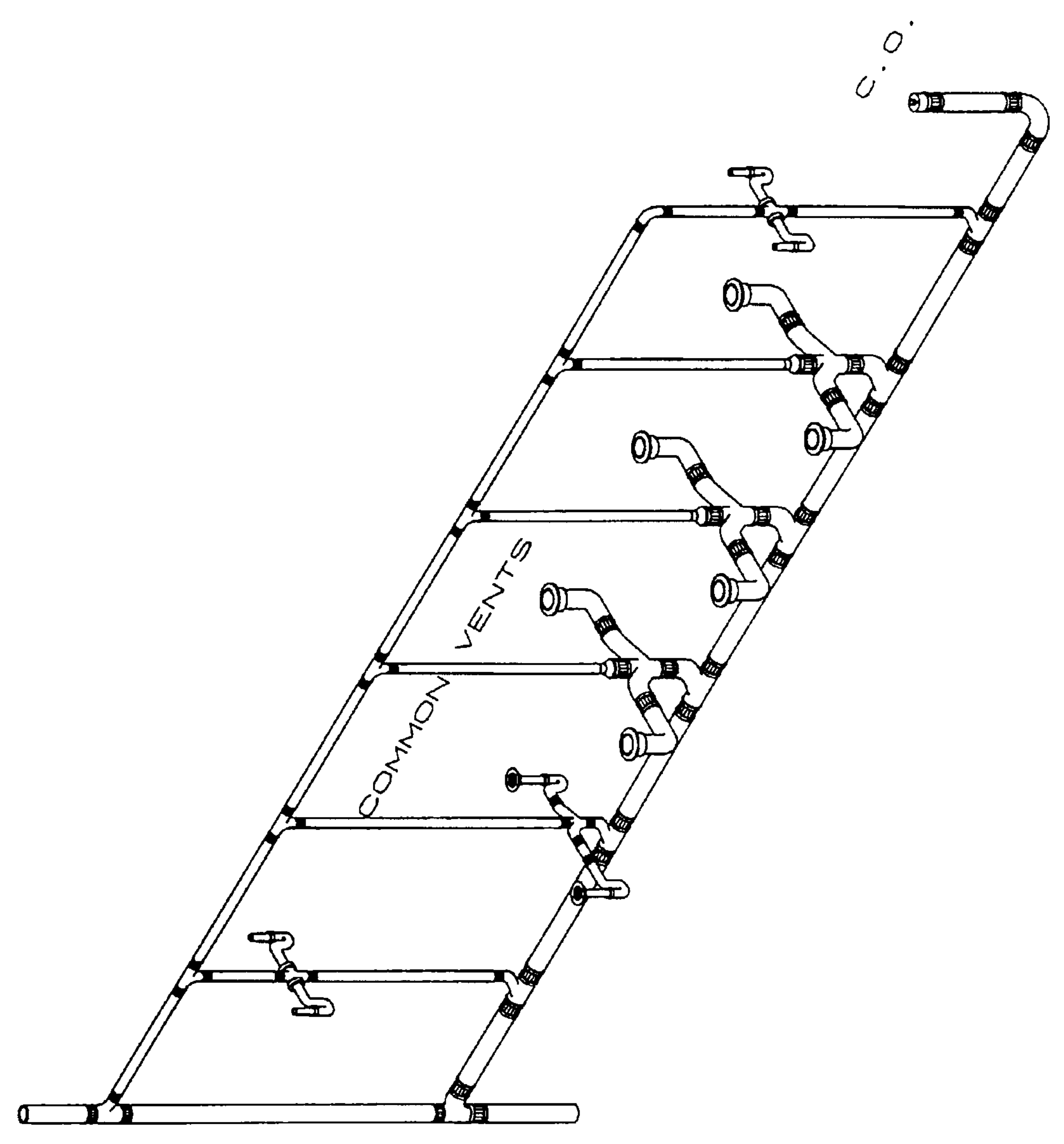


Vent Stack and Stack Vent.

Branch Vent.

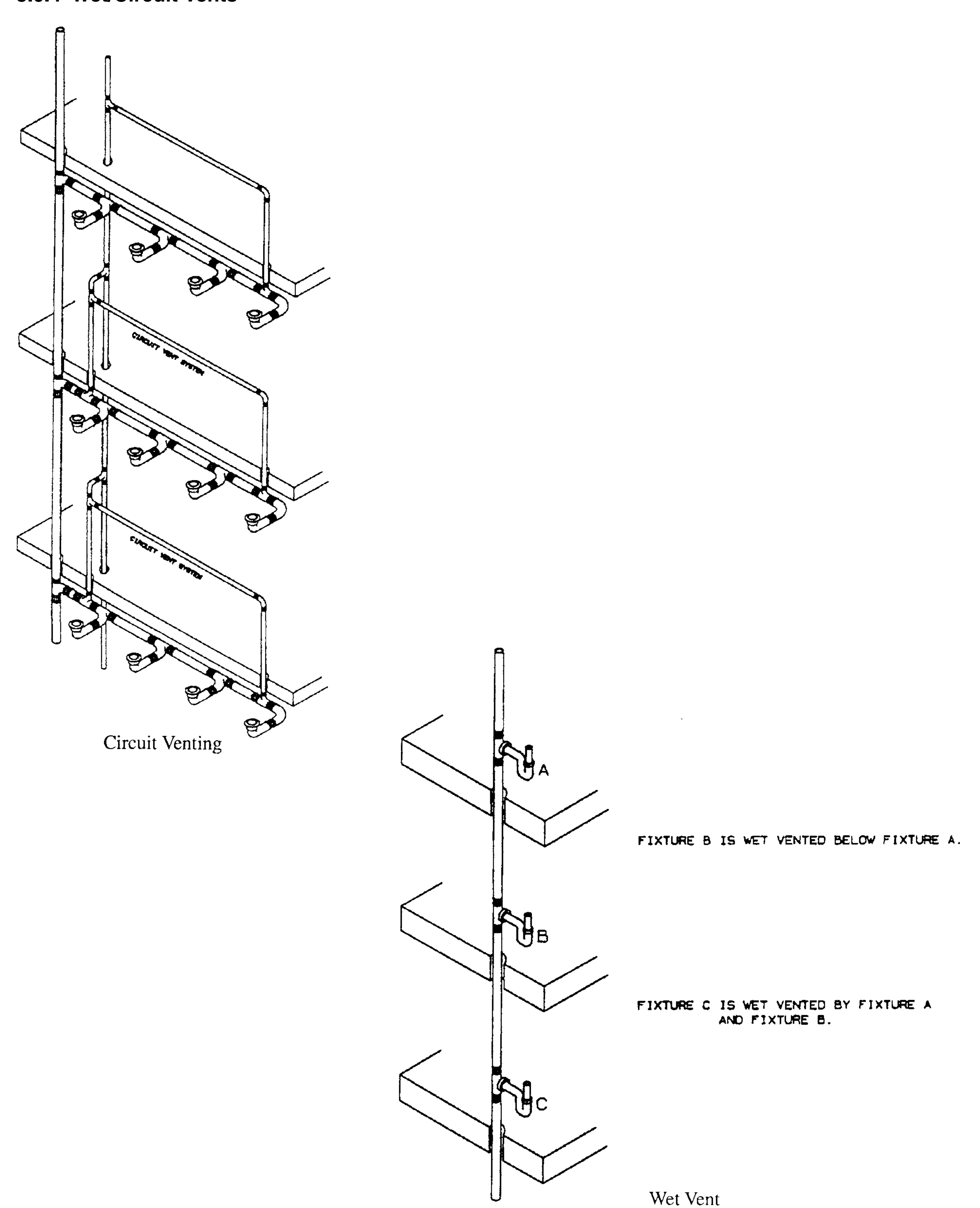
By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.0.3 Fixtures Using a Common Vent



By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.0.4 Wet/Circuit Vents

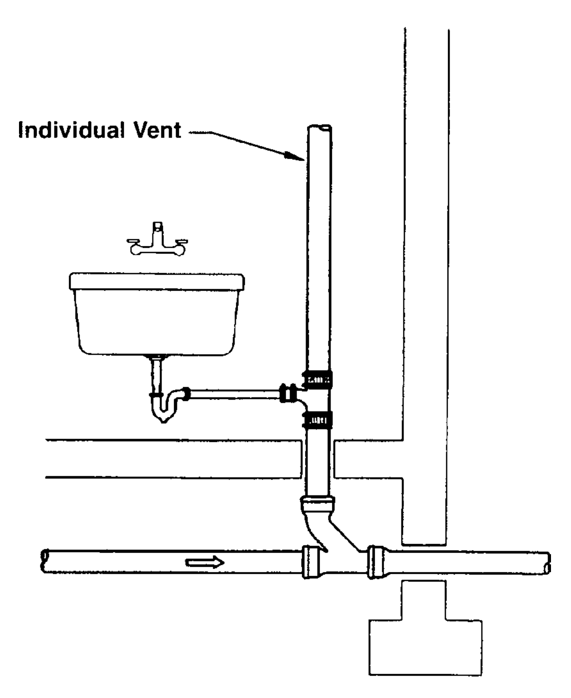


Circuit Venting

Wet Vent

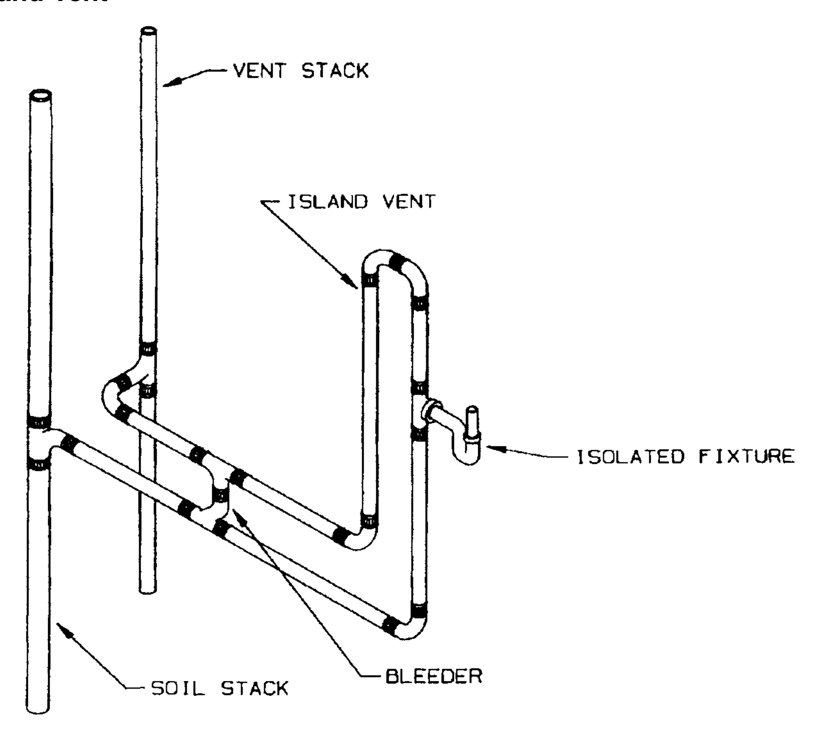
By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.0.5 Individual Vent



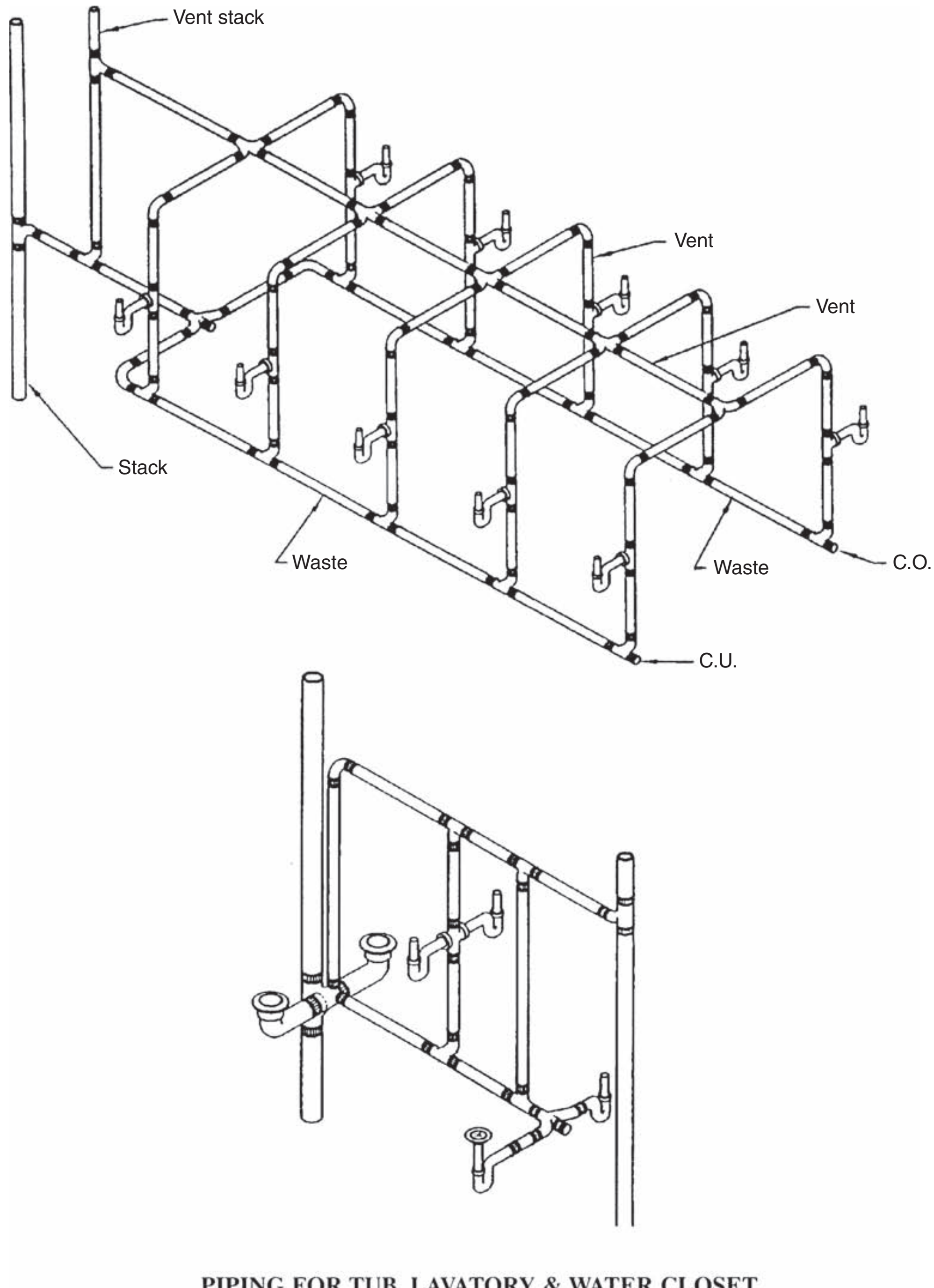
By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.0.6 Island Vent



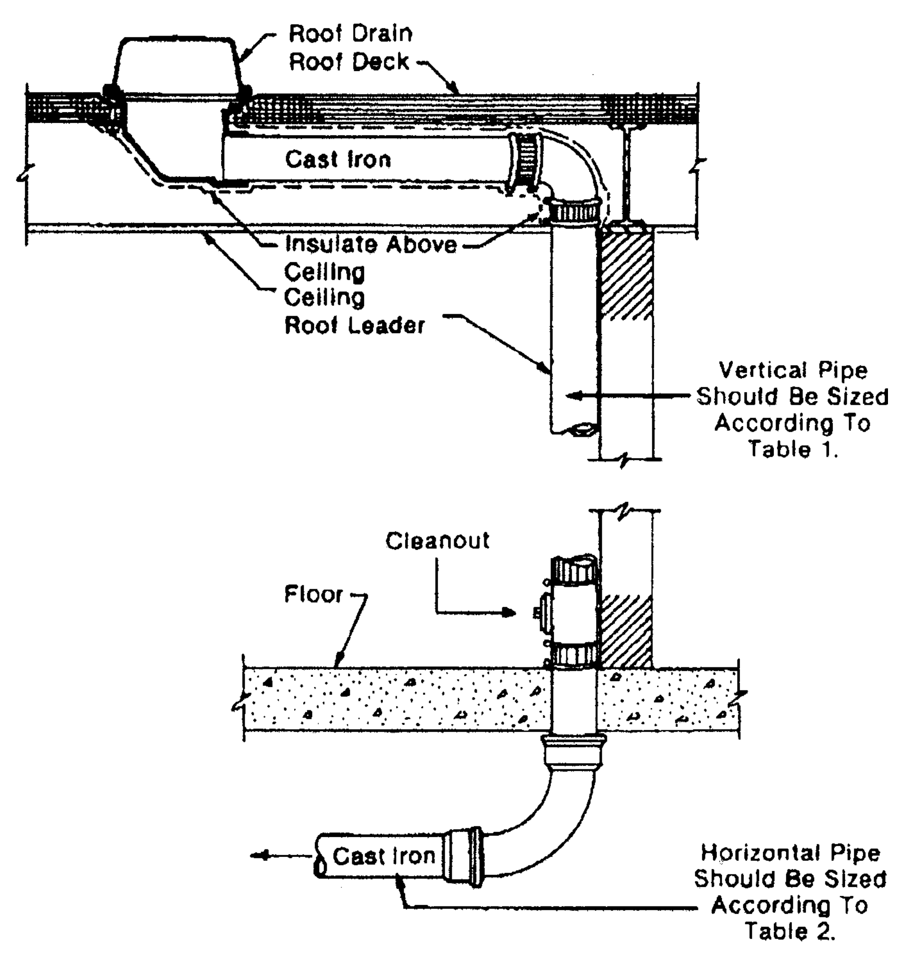
By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.0.7 Typical Bath Fixture Piping



By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.1.0 Roof Drains to Underground Systems



By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.1.1 Sizing Roof Drains

Rainfall in Inches	Size of Drain or Leader in Inches* 2	3	4	5	6	8
1	2880	8800	18400	34600	54000	116000
2	1440	4400	9200	17300	27000	58000
3	960	2930	6130	11530	17995	38660
4	720	2200	4600	8650	13500	29000
5	575	1760	3680	6920	10800	23200
6	480	1470	3070	5765	9000	19315
7	410	1260	2630	4945	7715	16570
8	360	1100	2300	4325	6750	14500
9	320	980	2045	3845	6000	12890
10	290	880	1840	3460	5400	11600
11	260	800	1675	3145	4910	10545
12	240	730	1530	2880	4500	9660

Source: Uniform Plumbing Code (IAPMO) 1985 Edition.
*Round, square or rectangular rainwater pipe may be used and are considered equivalent when closing a scribed circle equivalent to the leader diameter.

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8.2.0 Cast Iron Pipe Joints

The Compression Joint

The compression joint is the result of research and development to provide an efficient, lower-cost method for joining cast iron soil pipe and fittings. The joint is not unique in application to cast iron soil pipe, since similar compression-type gaskets have been used successfully in pressure pipe joints for years. As shown in Figure 1 (b), the compression joint uses hub and spigot pipe, as does the lead and oakum joint. The major difference is the one-piece rubber gasket.

When the spigot end of the pipe or fitting is pushed or drawn into the gasketed hub, the joint is sealed by displacement and compression of the rubber gasket. The resulting joint is leak-proof and root-proof. It absorbs vibration and can be deflected up to 5 degrees without leakage or failure.

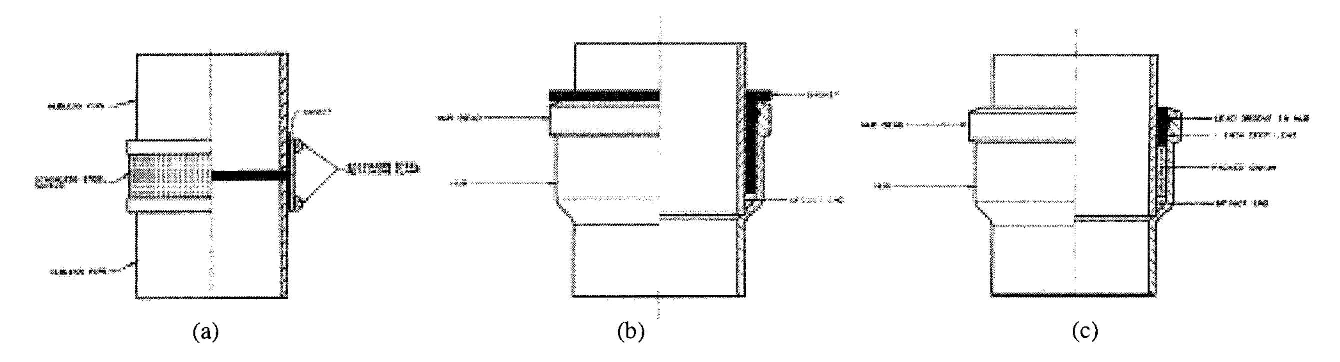


Figure 1—Typical Joints Used to Connect Cast Iron Soil Pipe and Fittings: (a) Typical Hubless Coupling; (b) Compression Joint; (c) Lead and Oakum Joint.

The Lead and Oakum Joint

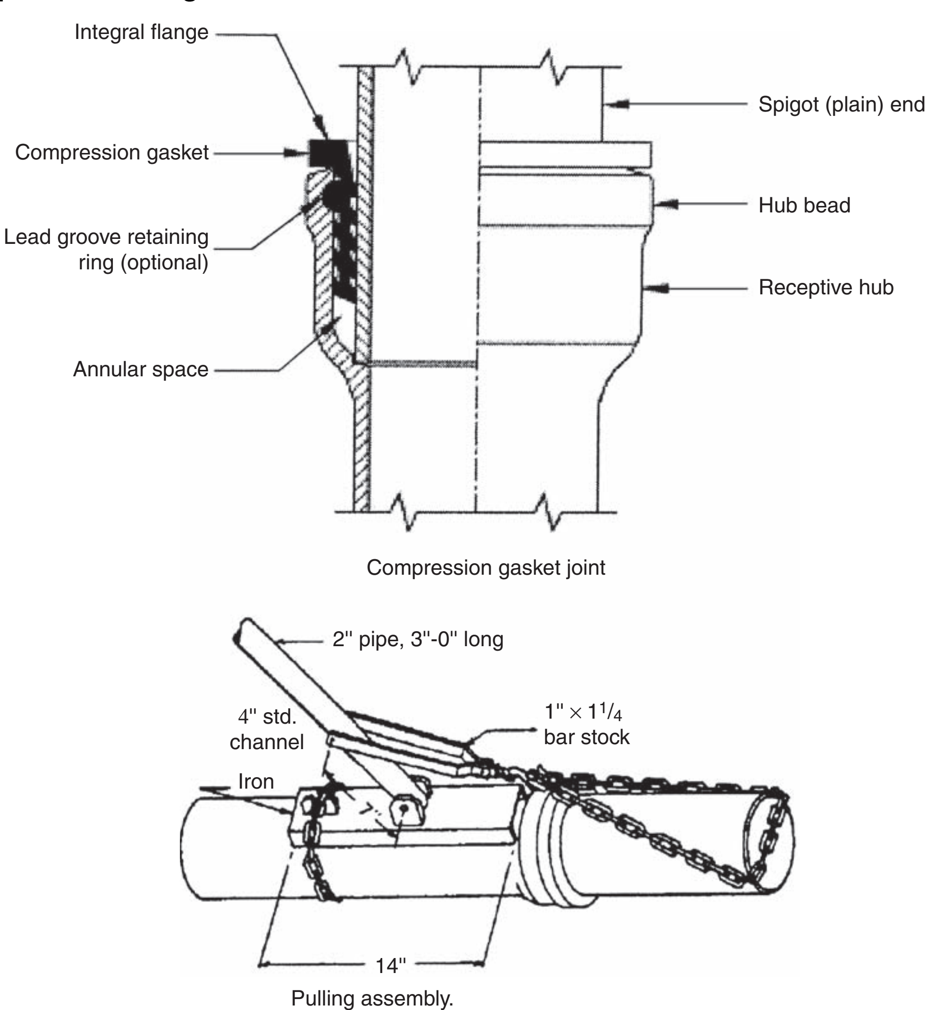
Cast iron soil pipe joints made with oakum fiber and molten lead are leak-proof, strong, flexible, and root-proof. The waterproofing characteristics of oakum fiber have long been recognized by the plumbing trades, and when molten lead is poured over the oakum in a cast iron soil pipe joint, it completely seals and locks the joint. This is due to the fact that the hot metal fills a groove in the bell end of the pipe, firmly anchoring the lead in place after cooling. When the lead has cooled sufficiently, it is caulked into the joint with a caulking tool to form a solid metal insert. The result is a lock-tight soil pipe joint with excellent flexural characteristics.

Soundproofing Qualities of Cast Iron With Rubber Gasket Joints

One of the most significant features of the compression gasketed joint and hubless coupling is that they assure a quieter plumbing drainage system. The problem of noise is particularly acute in multiple dwelling units. Although soundproofing has become a major concern in construction design, certain plumbing products have been introduced that not only transmit noise but in some cases actually amplify it. The use of neoprene gaskets and cast iron soil pipe reduces noise and vibration to an absolute minimum. Because of the density and wall thickness of the pipe, sound is muffled rather than transmitted or amplified, and the neoprene gaskets separate the lengths of pipe and the units of fittings so that they suppress any contact-related sound. The result is that objectionable plumbing noises are minimized.

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8.2.1 Compression Fittings



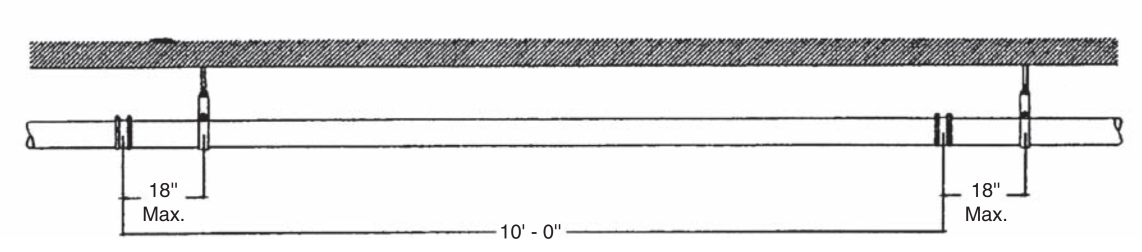
Pulling assembly.

By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.3.0 Hanger Spacing for Cast Iron Pipe

Installation Inside the Building

- According to most authorities and plumbing codes, it is sufficient to support horizontal pipe at each joint, i.e., five-inch pipe should be supported at five foot intervals, ten inch in length may be supported at ten-foot intervals. Supports should be adequate to maintain alignment and prevent sagging and should be placed within 18 inches of the joint.



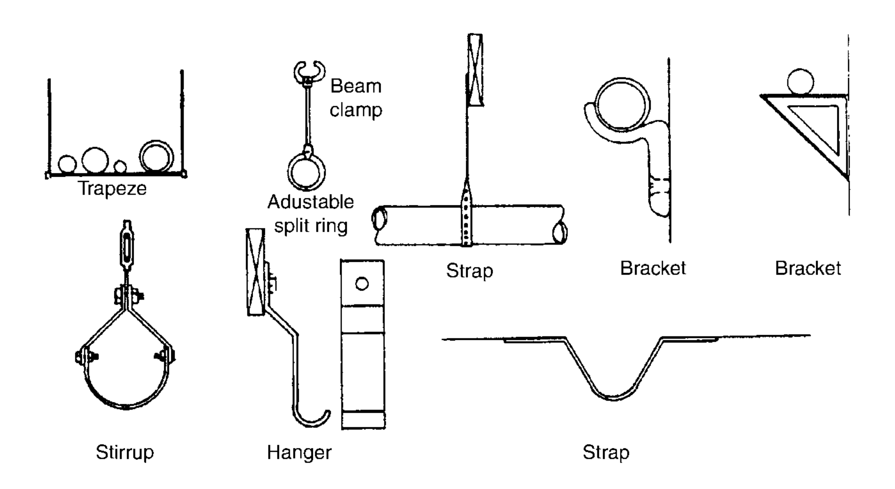
By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

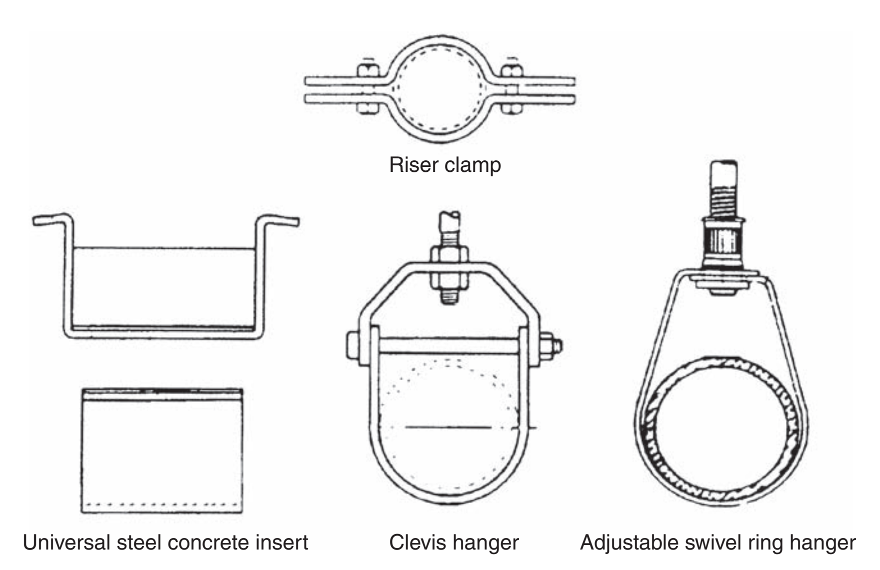
8.3.1 Horizontal Pipe Supports for Cast Iron Pipe

When the system is filled with water, sufficient beam strength is provided by cast iron soil pipe to carry the load with hangers every 10 feet. Any of the horizontal supports or clamps illustrated may be used, depending on conditions or what is regarded as essential by the contractor, architect, or engineer. Whatever method of support or clamp is used for the horizontal line, care should be exercised to make certain that the line has a proper grade (¼ inch or more per foot).

Hangers may be fastened to wood members or beams with wood screws, lag screws, or large nails. For fastening to "I" beams, bar joists, junior beams, or other structural members, beam clamps or "C" clamps may be used. Fasteners for masonry walls may be expansion bolts or screws, or where a void is present, toggle bolts may be used. Studs shot into the masonry by the explosion method may also be used. Along a wall, a bracket made of structural members or a cast bracket may be used.

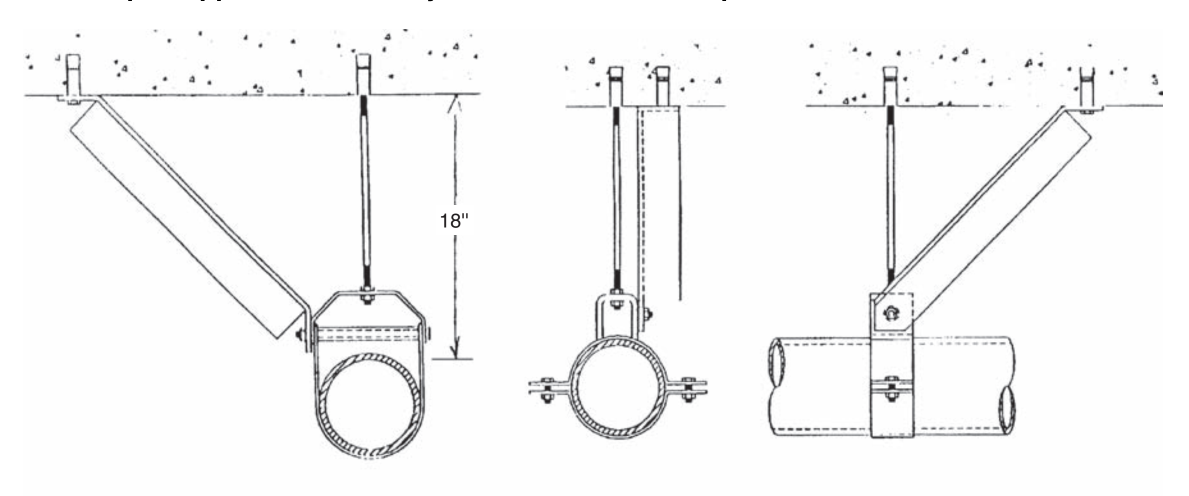
Adequate provision should be made to prevent "shear." Where components are suspended in excess of 18 inches by means of non-rigid hangers they should be suitably braced against horizontal movement, often called sway bracing.





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8.3.2 Horizontal Pipe Supports with a Sway Brace for Cast Iron Pipe



Horizontal Installation of Large Diameter Pipe

Horizontal pipe and fittings five inches and larger must be suitably braced to prevent horizontal movement. This must be done at every branch opening or change of direction by the use of braces, blocks, rodding or other suitable method, to prevent movement or joint separation.

Suggested Installation of Horizontal Fittings

- Hangers should be provided as necessary to provide alignment and grade. Hangers should be provided at each horizontal branch connection. Hangers should be adequate to maintain alignment and prevent sagging and should be placed adjacent to the coupling. By placing the hangers properly, the proper grade will be maintained. Adequate provision should be made to prevent shear.

By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.3.3 Plumbing Risers Secured

Vertical Piping

Vertical components should be secured at each stack base and at sufficiently close intervals to keep the system in alignment and to adequately support the weight of the pipe and its contents. Floor clamps, sometimes called friction clamps, are required for vertical piping in multistory structures so that each floor carries its share of the load. Figures 13 and 14 show some typical brackets or braces for vertical piping. Figure 15 shows a method of clamping the pipe at each floor using a friction or floor clamp.

If vertical piping is to stand free of any support, or if no structural element is available for support and stability during construction, secure the piping in its proper position by means of adequate metal stakes or braces fastened to the pipe.

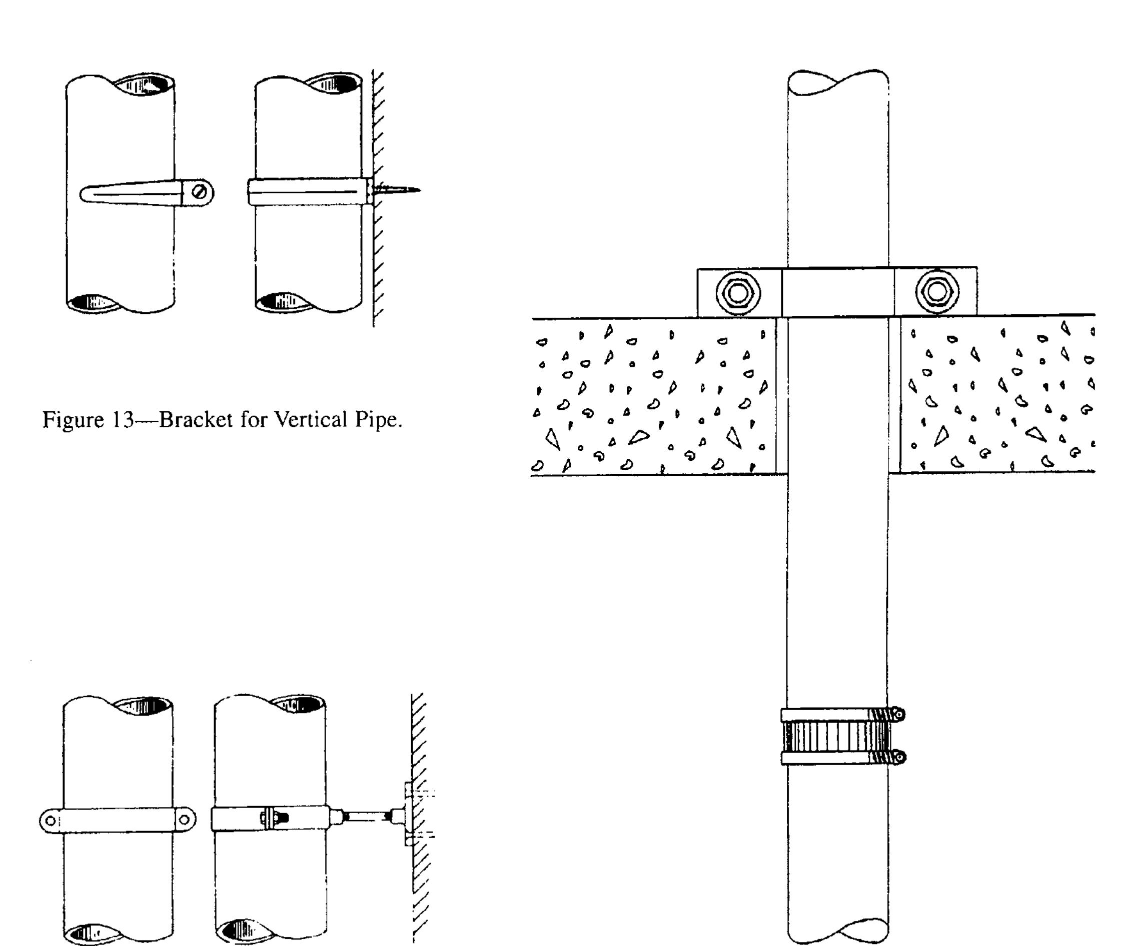


Figure 13—Bracket for Vertical Pipe.

Figure 14—One Hole Strap for Vertical Pipe.

Figure 15—Method of Clamping the Pipe at Each Floor, Using a Friction Clampor Floor Clamp.

By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.4.0 Fixture Trap Sizes

Fixture Units in a Plumbing Drainage System

Type of Fixture	Minimum Trap & Trap Arm Size (inches)	(mm)	Units
Bathtubs	1 1/2	(38.1)	2
Bidets	1 1/2	(38.1)	2
Dental units or cuspidors	1 1/4	(31.8)	1
Drinking fountains	1 1/4	(31.8)	1
Floor drains	2	(50.8)	2
*Interceptors for grease, oil, solids, etc.	2	(50.8)	3
*Interceptors for sand, auto wash, etc.	3	(76.2)	6
Laundry tubs	1 1/2	(38.1)	2
Clotheswashers	2	(50.8)	2
*Receptors (floor sinks), indirect waste receptors for refrigerators, dishwashers, airwashers, etc.	1 1/2	(38.1)	1
*Receptors, indirect waste receptors for commercial sinks, dishwashers, airwashers, etc.	2	(50.8)	3
Showers, single stalls	2	(50.8)	2
*Showers, gang, (one unit per head)	2	(50.8)	
Sinks, bar, private (1 1/2 in. (38.1 mm) min. waste)	1 1/2	(38.1)	2
Sinks, bar, commercial (2 in. (50.8 mm) min. waste)	1 1/2	(38.1)	2
Sinks, commercial or industrial, schools, etc. including dishwashers, wash up sinks and wash fountains (2 in. (50.8 mm) min. waste)	1 1/7	(38.1)	3
Sinks, flushing rim, clinic	3	(76.2)	6
Sinks, and/or dishwashers (residential) (2 in. (50.8 mm) min. waste)	1 1/2	(38.1)	2
Sinks, service	2	(50.8)	3
Mobile home park traps (one (1) for each trailer)	3	(76.2)	6
Urinals, pedestal, trap arm only	3	(76.2)	6
Urinals, stall	2	(50.8)	2
Urinals, wall (2 in. (50.8) min. waste)	1 1/2	(38.1)	2
Wash basins (lavatories) single	1 1/4	(31.8)	1
Wash basins, in sets	1 1/2	(38.1)	2
*Water closet, private installation, trap arm only	3	(76.2)	4
Water closet, public installation, trap arm only	3	(76.2)	6

*Note — The size and discharge rating of each indirect waste receptor and each interceptor shall be based on the total rated discharge capacity of all fixtures, equipment or appliances discharged thereinto, in accordance with Table 4.

Drainage piping serving batteries of appliances capable of producing continuous flows shall be adequately sized to provide for peak loads. Clotheswashers in groups of three or more shall be rated at six units each for the purpose of common waste pipe sizing.

Water closets shall be computed as six fixture units when determining septic tank size based on Appendix A of this publication.

Trap sizes shall not be increased to a point where the fixture discharge may be inadequate to maintain their self-scouring properties.

Source: Uniform Plumbing Code (IAPMO 1985 Edition)

By permission, The Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.5.0 Copper Plumbing and Heating Pipe—ASTM Standards

ASTM standards require a minimum of 99.9 percent pure copper. Copper pipe is available in types K, L, M, DWV, and medical gas tube.

- *Type K.* This copper pipe has the heaviest wall thickness, typically used for underground piping.
- *Type L.* Copper pipe with next thickest walls, used for most potable water and other above-grade plumbing applications.
- *Type M.* Copper pipe with the lightest walls, used for drainage and low-pressure piping applications.
- *ACR copper pipe*. Air-conditioning and refrigeration piping, designated with actual outside dimensions, comes in rolled lengths of 50 ft soft tempered and 20 ft in straight lengths.
- *DWV.* Drain, waste, vent is sold only in drawn temper (hard tube as opposed to "annealed" which is soft tube). This copper pipe is available in 1¼-, 1½-, 3-, and 4-in. diameters.
- *Medical gas.* This type is available as either type K or type L, in nominal sizes ranging from ¼ to 8 in. Special requirements are called for to ensure that the tubing or pipe is properly cleaned and capped or plugged to prevent contamination.

8.5.0.1 Selecting the Right Tube for the Job

Advantages of Copper Tube

Strong, corrosion resistant, copper tube is the leading choice of modern contractors for plumbing, heating and cooling installations in all kinds of residential and commercial buildings. There are seven primary reasons for this:

1. ***Copper is economical.*** The combination of easy handling, forming and joining permits savings in installation time, material and overall costs. Long-term performance and reliability mean fewer callbacks, and that makes copper the ideal cost-effective tubing material.

2. ***Copper is lightweight.*** Copper tube does not require the heavy thickness of ferrous or threaded pipe of the same internal diameter. This means copper costs less to transport, handles more easily and, when installed, takes less space.

3. ***Copper is formable.*** Because copper tube can be bent and formed, it is frequently possible to eliminate elbows and joints. Smooth bends permit the tube to follow contours and corners of almost any angle. With soft temper tube, particularly when used for renovation or modernization projects, much less wall and ceiling space is needed.

4. ***Copper is easy to join.*** Copper tube can be joined with capillary fittings. These fittings save material and make smooth, neat, strong and leak-proof joints. No extra thickness or weight is necessary to compensate for material removed by threading.

5. ***Copper is safe.*** Copper tube will not burn or support combustion and decompose to toxic gases. Therefore, it will not carry fire through floors, walls and ceilings. Volatile organic compounds are not required for installation.

6. ***Copper is dependable.*** Copper tube is manufactured to well-defined composition standards and marked with permanent identification so you know exactly what it is and who made it. It is accepted by virtually every plumbing code.

7. ***Copper resists corrosion.*** Excellent resistance to corrosion and scaling assures long, trouble-free service, which means satisfied customers.

Minimum Recommendations for Various Applications

It is up to the designer to select the type of copper tube for use in a particular application. Strength, formability and other mechanical factors often determine the choice. Plumbing and mechanical codes govern what types may be used. When a choice can be made, it is helpful to know which type of copper tube has and can serve successfully and economically in the following applications:

Underground Water Services—Use Type M hard for straight lengths joined with fittings, and Type L soft where coils are more convenient.

Water Distribution Systems—Use Type M for above and below ground.

Chilled Water Mains—Use Type M for all sizes.

Drainage and Vent Systems—Use Type DWV for above- and below-ground waste, soil and vent lines, roof and building drains and sewers.

Heating—For radiant panel and hydronic heating and for snow melting systems, use Type L soft temper where coils are formed in place or prefabricated, Type M where straight lengths are used. For water heating and low-pressure steam, use Type M for all sizes. For condensate return lines, Type L is successfully used.

Solar Heating—See Heating section above. For information on solar installation and on solar collectors, write CDA.

Fuel Oil, L.P. and Natural Gas Services—Use Type L or Type ACR tube with flared joints in accessible locations and brazed joints made using AWS A5.8 BAg series brazing filler metals in concealed locations.

Nonflammable Medical Gas Systems—Use Medical Gas tube Types K or L, suitably cleaned for oxygen service per NFPA Standard No. 99, *Health Care Facilities*.

Air-Conditioning and Refrigeration Systems—Copper is the preferred material for use with most refrigerants. Use Types L, ACR or as specified.

Ground Source Heat Pump Systems—Use Types L or ACR where the ground coils are formed in place or prefabricated, or as specified.

Fire Sprinkler Systems—Use Type M hard. Where bending is required, Types K or L are recommended. Types K, L and M are all accepted by NFPA.

Low Temperature Applications – Use copper tube of Type determined by rated internal working pressures at room temperature. Copper tube retains excellent ductility at low temperatures to −452°F and yield strength and tensile strength increase as temperature is reduced to this point. This plus its excellent thermal conductivity makes an unusual combination of properties for heat exchangers, piping, and other components in cryogenic plants and other low temperature applications.

Compressed Air—Use copper tube of Types K, L or M determined by the rated internal working pressures. Brazed joints are recommended.

By permission, Copper Development Association.

8.5.0.2 Copper Tube Types, Standards, Applications

Tube Type	Color Code	Standard	Application[1]	Commercially Available Lengths[2]		
				Nominal or Standard Sizes	Drawn	Annealed
TYPE K	Green	ASTM B 88[3]	Domestic Water Service and Distribution, Fire Protection, Solar, Fuel/Fuel Oil, HVAC, Snow Melting, Compressed Air, Natural Gas, Liquified Petroleum (LP) Gas, Vacuum	STRAIGHT LENGTHS:		
				1/4-inch to 8-inch	20 ft	20 ft
				10-inch	18 ft	18 ft
				12-inch	12 ft	12 ft
				COILS:		
				1/4-inch to 1-inch	—	60 ft
					—	100 ft
				1 1/4 inch and 1 1/2-inch	—	60 ft
				2-inch	—	40 ft
					—	45 ft
TYPE L	Blue	ASTM B 88	Domestic Water Service and Distribution, Fire Protection, Solar, Fuel/Fuel Oil, Natural Gas, Liquified Petroleum (LP) Gas, HVAC, Snow Melting, Compressed Air, Vacuum	STRAIGHT LENGTHS:		
				1/4-inch to 10-inch	20 ft	20 ft
				12-inch	18 ft	18 ft
				COILS:		
				1/4-inch to 1-inch	—	60 ft
					—	100 ft
				1 1/4 inch and 1 1/2-inch	—	60 ft
				2-inch	—	40 ft
					—	45 ft
TYPE M	Red	ASTM B 88	Domestic Water Service and Distribution, Fire Protection, Solar, Fuel/Fuel Oil, HVAC, Snow Melting, Vacuum	STRAIGHT LENGTHS:		
				1/4-inch to 12-inch	20 ft	N/A
DWV	Yellow	ASTM B 306	Drain, Waste, Vent, HVAC, Solar	STRAIGHT LENGTHS:		
				1 1/4-inch to 8-inch	20 ft	N/A
ACR	Blue	ASTM B 280	Air Conditioning, Refrigeration, Natural Gas, Liquified Petroleum (LP) Gas, Compressed Air	STRAIGHT LENGTHS:		
				3/8-inch to 4 1/8-inch	20 ft	[4]
				COILS:		
				1/8-inch to 1 5/8-inch	—	50 ft
OXY, MED, OXY/MED, OXY/ACR, ACR/MED	(K)Green (L)Blue	ASTM B 819	Medical Gas Compressed Medical Air, Vacuum	STRAIGHT LENGTHS:		
				1/4-inch to 8-inch	20 ft	N/A

1. There are many other copper and copper alloy tubes and pipes available for specialized applications. For information on these products, contact the Copper Development Association Inc.

2. Individual manufacturers may have commercially available lengths in addition to those shown in this table.

3. Tube made to other ASTM standards is also intended for plumbing applications, although ASTM B 88 is by far the most widely used. ASTM Standard Classification B 698 lists six plumbing tube standards including B 88.

4. Available as special order only.

8.5.1 Designing, Installing Copper Pipe per Copper Development Association Standards

1. Tube end should be reamed to remove any burrs left inside after it has been cut. These burrs can create cavitation and interrupted flow downstream from the unreamed tube; the reduced flow will allow air bubbles entrained in the water to escape and scour the tube and fittings walls, thereby creating pits that may cause failure over the long term.
2. Either an undersized piping system or an oversized recirculating pump may create high water velocity. Recommended velocities for cold water systems are 5 to 8 feet per second (fps) (1.5 to 2.4 m/s) and 4 to 5 fps (1.2 to 1.5 m/s) for hot water systems with temperatures less than 140°F (78°C) and 2 to 3 fps (61 to 91 cm/s) for hot water with a temperature greater than 140°F (78°C).
3. Avoid abrupt changes in the direction of piping that can interrupt laminar flow. Use long-radius (1.5 × diameter) fittings to minimize interruption to flow.
4. Avoid protrusions into the flow stream, such as excessive lumps of solder or brazing materials.
5. Heating water above 140°F (78°C) can accelerate the erosion and corrosion process in copper pipe.
6. Excessive amounts of dissolved gases or suspended solids, traveling at high velocities in water, can impinge the inner surface of the copper pipe, causing erosion and corrosion.

8.5.2 Dimensions, Characteristics—Type K Copper Tubing

Nominal or Standard Size, inches	Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)				
	Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	Weight of Tube Only, pounds per linear ft	Weight of Tube & Water, pounds per linear ft	Contents of Tube per linear ft: Cu ft	Contents of Tube per linear ft: Gal
1/4	.375	.305	.035	.073	.145	.177	.00051	.00379
3/8	.500	.402	.049	.127	.269	.324	.00088	.00660
1/2	.625	.527	.049	.218	.344	.438	.00151	.0113
5/8	.750	.652	.049	.334	.418	.562	.00232	.0174
3/4	.875	.745	.065	.436	.641	.829	.00303	.0227
1	1.125	.995	.065	.778	.839	1.18	.00540	.0404
1 1/4	1.375	1.245	.065	1.22	1.04	1.57	.00847	.0634
1 1/2	1.625	1.481	.072	1.72	1.36	2.10	.0119	.0894
2	2.125	1.959	.083	3.01	2.06	3.36	.0209	.156
2 1/2	2.625	2.435	.095	4.66	2.93	4.94	.0324	.242
3	3.125	2.907	.109	6.64	4.00	6.87	.0461	.345
3 1/2	3.625	3.385	.120	9.00	5.12	9.01	.0625	.468
4	4.125	3.857	.134	11.7	6.51	11.6	.0813	.608
5	5.125	4.805	.160	18.1	9.67	17.5	.126	.940
6	6.125	5.741	.192	25.9	13.9	25.1	.180	1.35
8	8.125	7.583	.271	45.2	25.9	45.4	.314	2.35
10	10.125	9.449	.338	70.1	40.3	70.6	.487	3.64
12	12.125	11.315	.405	101	57.8	101	.701	5.25

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8.5.3 Dimensions, Characteristics—Type L Copper Tubing

Nominal or Standard Size, inches	Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)				
	Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	Weight of Tube Only, pounds per linear ft	Weight of Tube & Water, pounds per linear ft	Contents of Tube per linear ft Cu ft	Gal
1/4	.375	.315	.030	.078	.126	.160	.00054	.00405
3/8	.500	.430	.035	.145	.198	.261	.00101	.00753
1/2	.625	.545	.040	.233	.285	.386	.00162	.0121
5/8	.750	.666	.042	.348	.362	.506	.00232	.0174
3/4	.875	.785	.045	.484	.455	.664	.00336	.0251
1	1.125	1.025	.050	.825	.655	1.01	.00573	.0429
1 1/4	1.375	1.265	.055	1.26	.884	1.43	.00875	.0655
1 1/2	1.625	1.505	.060	1.78	1.14	1.91	.0124	.0925
2	2.125	1.985	.070	3.09	1.75	3.09	.0215	.161
2 1/2	2.625	2.465	.080	4.77	2.48	4.54	.0331	.248
3	3.125	2.945	.090	6.81	3.33	6.27	.0473	.354
3 1/2	3.625	3.425	.100	9.21	4.29	8.27	.0640	.478
4	4.125	3.905	.110	12.0	5.38	10.1	.0764	.571
5	5.125	4.875	.125	18.7	7.61	15.7	.130	.971
6	6.125	5.845	.140	26.8	10.2	21.8	.186	1.39
8	8.125	7.725	.200	46.9	19.3	39.6	.326	2.44
10	10.125	9.625	.250	72.8	30.1	61.6	.506	3.78
12	12.125	11.565	.280	105	40.4	85.8	.729	5.45

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8.5.4 Dimensions, Characteristics—Type M Copper Tubing

Nominal or Standard Size, inches	Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)				
	Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	Weight of Tube Only, pounds per linear ft	Weight of Tube & Water, pounds per linear ft	Contents of Tube per linear ft Cu ft	Gal
3/8	.500	.450	.025	.159	.145	.214	.00110	.00826
1/2	.625	.569	.028	.254	.204	.314	.00176	.0132
3/4	.875	.811	.032	.517	.328	.551	.00359	.0269
1	1.125	1.055	.035	.874	.465	.843	.00607	.0454
1 1/4	1.375	1.291	.042	1.31	.682	1.25	.00910	.0681
1 1/2	1.625	1.527	.049	1.83	.940	1.73	.0127	.0951
2	2.125	2.009	.058	3.17	1.46	2.83	.0220	.165
2 1/2	2.625	2.495	.065	4.89	2.03	4.14	.0340	.254
3	3.125	2.981	.072	6.98	2.68	5.70	.0485	.363
3 1/2	3.625	3.459	.083	9.40	3.58	7.64	.0653	.488
4	4.125	3.935	.095	12.2	4.66	9.83	.0847	.634
5	5.125	4.907	.109	18.9	6.66	14.8	.131	.982
6	6.125	5.881	.122	27.2	8.92	20.7	.189	1.41
8	8.125	7.785	.170	47.6	16.5	37.1	.331	2.47
10	10.125	9.701	.212	73.9	25.6	57.5	.513	3.84
12	12.125	11.617	.254	106	36.7	82.5	.736	5.51

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8.5.5 Dimensions, Characteristics—Type DWV Copper Tubing

Dimensions and Physical Characteristics of Copper Tube: DWV (Drain, Waste and Vent)

Nominal or Standard Size, inches	Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)				
	Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	Weight of Tube Only, pounds per linear ft	Weight of Tube & Water, pounds per linear ft	Contents of Tube per linear ft Cu ft	Contents of Tube per linear ft Gal
1¼	1.375	1.295	.040	1.32	.650	1.22	.00917	.0686
1½	1.625	1.541	.042	1.87	.809	1.62	.0130	.0971
2	2.125	2.041	.042	3.27	1.07	2.48	.0227	.170
3	3.125	3.030	.045	7.21	1.69	4.81	.0501	.375
4	4.125	4.009	.058	11.6	2.87	7.88	.0806	.603
5	5.125	4.981	.072	19.5	4.43	12.9	.135	1.01
6	6.125	5.959	.083	27.9	6.10	18.2	.194	1.45
8	8.125	7.907	.109	49.1	10.6	31.8	.341	2.55

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8.5.6 Dimensions, Characteristics—Medical Gas Type Copper Tubing

Dimensions and Physical Characteristics of Copper Tube: Medical Gas, K and L

Nominal or Standard Size, inches		Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)			
		Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	Internal surface, sq feet per linear ft	Weight of Tube Only, pounds per linear ft	Contents of Tube, cu feet per linear ft
¼	K	.375	.305	.035	.073	.0789	.145	.00051
	L	.375	.315	.030	.078	.0825	.126	.00054
⅜	K	.500	.402	.049	.127	.105	.269	.00088
	L	.500	.430	.035	.145	.113	.198	.00101
½	K	.625	.527	.049	.218	.130	.344	.00151
	L	.625	.545	.040	.233	.143	.285	.00162
⅝	K	.750	.652	.049	.334	.171	.418	.00232
	L	.750	.666	.042	.348	.174	.362	.00242
¾	K	.875	.745	.065	.436	.195	.641	.00303
	L	.875	.785	.045	.484	.206	.455	.00336
1	K	1.125	.995	.065	.778	.261	.839	.00540
	L	1.125	1.025	.050	.825	.268	.655	.00573
1¼	K	1.375	1.245	.065	1.222	.326	1.04	.00845
	L	1.375	1.265	.055	1.26	.331	.884	.00873
1½	K	1.625	1.481	.072	1.72	.388	1.36	.0120
	L	1.625	1.505	.060	1.78	.394	1.14	.0124
2	K	2.125	1.959	.083	3.01	.522	2.06	.0209
	L	2.125	1.985	.070	3.09	.520	1.75	.0215
2½	K	2.625	2.435	.095	4.66	.638	2.93	.0323
	L	2.625	2.465	.080	4.77	.645	2.48	.0331
3	K	3.125	2.907	.109	6.64	.761	4.00	.0461
	L	3.125	2.945	.090	6.81	.761	3.33	.0473
3½	K	3.625	3.385	.120	9.00	.886	5.12	.0625
	L	3.625	3.425	.100	9.21	.897	4.29	.0640
4	K	4.125	3.857	.134	11.7	1.01	6.51	.0811
	L	4.125	3.905	.110	12.0	1.02	5.38	.0832
5	K	5.125	4.805	.160	18.1	1.26	9.67	.126
	L	5.125	4.875	.125	18.7	1.28	7.61	.130
6	K	6.125	5.741	.192	25.9	1.50	13.9	.180
	L	6.125	5.854	.140	26.8	1.53	10.2	.186
8	K	8.125	7.583	.271	45.2	1.99	25.9	.314
	L	8.125	7.725	.200	46.9	2.02	19.3	.325

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8.5.7 Dimensions, Characteristics—ACR (Air-Conditioning and Refrigeration) Copper

Dimensions and Physical Characteristics of Copper Tube: ACR (Air-Conditioning and Refrigeration Field Service) (A= Annealed Temper, D=Drawn Temper)

Nominal or Standard Size, inches		Nominal Dimensions, inches			Calculated Values (based on nominal dimensions)				
		Outside Diameter	Inside Diameter	Wall Thickness	Cross Sectional Area of Bore, sq inches	External Surface, sq ft per linear ft	Internal Surface, sq ft per linear ft	Weight of Tube Only, pounds per linear ft	Contents of Tube, cu ft per linear ft
1/8	A	.125	.065	.030	.00332	.0327	.0170	.0347	.00002
3/16	A	.187	.128	.030	.0129	.0492	.0335	.0575	.00009
1/4	A	.250	.190	.030	.0284	.0655	.0497	.0804	.00020
5/16	A	.312	.248	.032	.0483	.0817	.0649	.109	.00034
3/8	A	.375	.311	.032	.076	.0982	.0814	.134	.00053
	D	.375	.315	.030	.078	.0982	.0821	.126	.00054
1/2	A	.500	.436	.032	.149	.131	.114	.182	.00103
	D	.500	.430	.035	.145	.131	.113	.198	.00101
5/8	A	.625	.555	.035	.242	.164	.145	.251	.00168
	D	.625	.545	.040	.233	.164	.143	.285	.00162
3/4	A	.750	.680	.035	.363	.196	.178	.305	.00252
	A	.750	.666	.042	.348	.196	.174	.362	.00242
	D	.750	.666	.042	.348	.196	.174	.362	.00242
7/8	A	.875	.785	.045	.484	.229	.206	.455	.00336
	D	.875	.785	.045	.484	.229	.206	.455	.00336
1 1/8	A	1.125	1.025	.050	.825	.294	.268	.655	.00573
	D	1.125	1.025	.050	.825	.294	.268	.655	.00573
1 3/8	A	1.375	1.265	.055	1.26	.360	.331	.884	.00875
	D	1.375	1.265	.055	1.26	.360	.331	.884	.00875
1 5/8	A	1.625	1.505	.060	1.78	.425	.394	1.14	.0124
	D	1.625	1.505	.060	1.78	.425	.394	1.14	.0124
2 1/8	D	2.125	1.985	.070	3.09	.556	.520	1.75	.0215
2 5/8	D	2.625	2.465	.080	4.77	.687	.645	2.48	.0331
3 1/8	D	3.125	2.945	.090	6.81	.818	.771	3.33	.0473
3 5/8	D	3.625	3.425	.100	9.21	.949	.897	4.29	.0640
4 1/8	D	4.125	3.905	.110	12.0	1.08	1.02	5.38	.0833

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8.5.8 Pressure Loss in Copper Fittings, Valves

Pressure Loss in Fittings and Valves Expressed as Equivalent Length of Tube, feet

Nominal or Standard Size, in	Fittings					Valves			
	Standard Ell		90° Tee		Coupling				
	90°	45°	Side Branch	Straight Run		Ball	Gate	Btfly	Check
3/8	.5	—	1.5	—	—	—	—	—	1.5
1/2	1	.5	2	—	—	—	—	—	2
5/8	1.5	.5	2	—	—	—	—	—	2.5
3/4	2	.5	3	—	—	—	—	—	3
1	2.5	1	4.5	—	—	.5	—	—	4.5
1 1/4	3	1	5.5	.5	.5	.5	—	—	5.5
1 1/2	4	1.5	7	.5	.5	.5	—	—	6.5
2	5.5	2	9	.5	.5	.5	.5	7.5	9
2 1/2	7	2.5	12	.5	.5	—	1	10	11.5
3	9	3.5	15	1	1	—	1.5	15.5	14.5
3 1/2	9	3.5	14	1	1	—	2	—	12.5
4	12.5	5	21	1	1	—	2	16	18.5
5	16	6	27	1.5	1.5	—	3	11.5	23.5
6	19	7	34	2	2	—	3.5	13.5	26.5
8	29	11	50	3	3	—	5	12. 5	39

NOTES: Allowances are for streamlined soldered fittings and recessed threaded fittings.
For threaded fittings, double the allowances shown in the table.
The equivalent lengths presented above are based upon a C factor of 150 in the Hazen-Williams friction loss formula. The lengths shown are rounded to the nearest half foot.

8.5.9 Solder Requirements for Joint Pressure Fittings

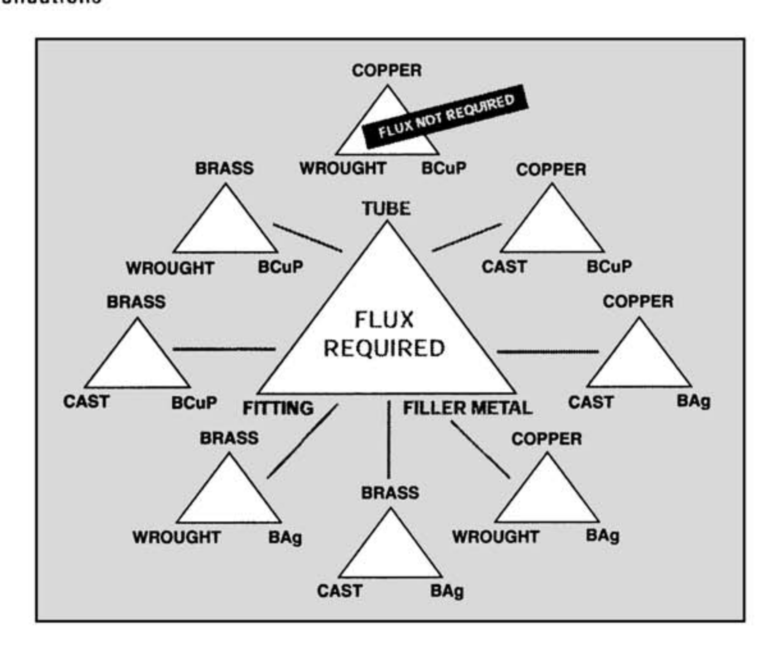
Solder Requirements for Solder Joint Pressure Fittings, length in inches[1]

Nominal or Standard Size, inches	O.D. of Tube, inches	Cup Depth of Fitting, inches	Joint Clearance, inches 0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.010	Wt. in lbs at .010 clearance per 100 joints
1/4	.375	.310	.030	.060	.089	.119	.149	.179	.208	.238	.268	.298	.097
3/8	.500	.380	.049	.097	.146	.195	.243	.292	.341	.389	.438	.486	.159
1/2	.625	.500	.080	.160	.240	.320	.400	.480	.560	.640	.720	.800	.261
5/8	.750	.620	.119	.238	.357	.476	.595	.714	.833	.952	1.072	1.191	.389
3/4	.875	.750	.168	.336	.504	.672	.840	1.008	1.176	1.344	1.512	1.680	.548
1	1.125	.910	.262	.524	.786	1.048	1.311	1.573	1.835	2.097	2.359	2.621	.856
1 1/4	1.375	.970	.341	.683	1.024	1.366	1.707	2.049	2.390	2.732	3.073	3.415	1.115
1 1/2	1.625	1.090	.454	.907	1.361	1.814	2.268	2.721	3.175	3.628	4.082	4.535	1.480
2	2.125	1.340	.729	1.458	2.187	2.916	3.645	4.374	5.103	5.833	6.562	7.291	2.380
2 1/2	2.625	1.470	.988	1.976	2.964	3.952	4.940	5.928	6.916	7.904	8.892	9.880	3.225
3	3.125	1.660	1.328	2.656	3.985	5.313	6.641	7.969	9.297	10.626	11.954	13.282	4.335
3 1/2	3.625	1.910	1.773	3.546	5.318	7.091	8.864	10.637	12.409	14.182	15.955	17.728	5.786
4	4.125	2.160	2.281	4.563	6.844	9.125	11.407	13.688	15.969	18.250	20.532	22.813	7.446
5	5.125	2.660	3.490	6.981	10.471	13.962	17.452	20.943	24.433	27.924	31.414	34.905	11.392
6	6.125	3.090	4.846	9.692	14.538	19.383	24.229	29.075	33.921	38.767	43.613	48.459	15.815
8	8.125	3.970	8.259	16.518	24.777	33.035	41.294	49.553	57.812	66.071	74.330	82.589	26.955
10	10.125	4.000	10.370	20.739	31.109	41.478	51.848	62.218	72.587	82.957	93.326	103.696	33.845
12	12.125	4.500	13.970	27.940	41.910	55.881	69.851	83.821	97.791	111.761	125.731	139.701	45.596
							Average Actual Consumption[2]					For Estimating Purposes[3]	

[1] Using 1/8-inch diameter (No. 9) Wire Solder (1 inch length = .01227 cubic inches).
[2] Actual consumption depends on workmanship.
[3] Includes an allowance of 100% to cover wastage and loss.

NOTE: Flux requirements are usually 2 oz per lb of solder.

Brazing Flux Recommendations



Triangles, denoting when to use flux, are surrounded by tube type, fitting type and brazing filler type.

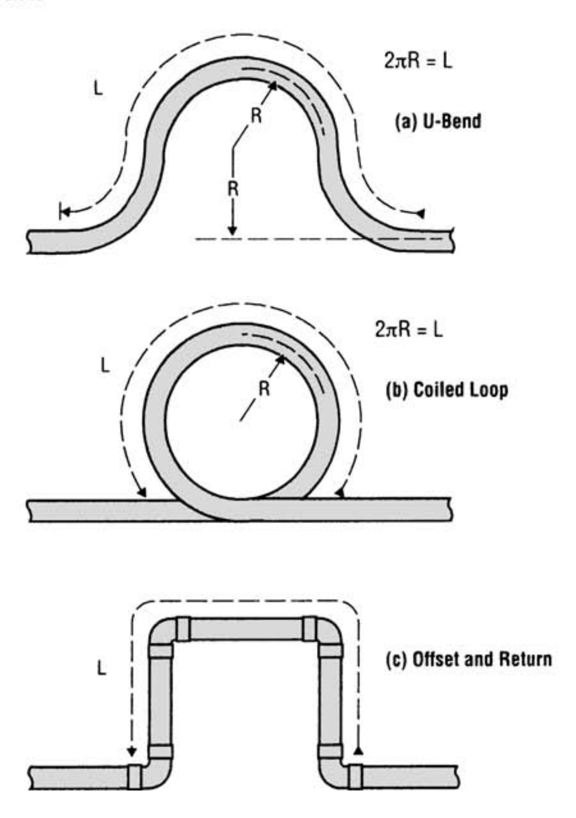
NOTE: When joining copper tube to a wrought fitting using BCup filler, **no** flux is required.

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8.5.10 Radii of Coiled Expansion Loops and Offsets

Expected Expansion, inches		Radius "R", inches, for Nominal or Standard Tube Sizes Shown Length "L", inches, for Nominal or Standard Tube Sizes Shown												
		1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5
1/2	R	6	7	8	9	11	12	13	15	16	18	19	20	23
	L	38	44	50	59	67	74	80	91	102	111	120	128	142
1	R	9	10	11	13	15	17	18	21	23	25	27	29	32
	L	54	63	70	83	94	104	113	129	144	157	169	180	201
1 1/2	R	11	12	14	16	18	20	22	25	28	30	33	35	39
	L	66	77	86	101	115	127	138	158	176	191	206	220	245
2	R	12	14	16	19	21	23	25	29	32	35	38	41	45
	L	77	89	99	117	133	147	160	183	203	222	239	255	284
2 1/2	R	14	16	18	21	24	26	29	33	36	40	43	45	51
	L	86	99	111	131	149	165	179	205	227	248	267	285	318
3	R	15	17	19	23	26	29	31	36	40	43	47	50	55
	L	94	109	122	143	163	180	196	224	249	272	293	312	348
3 1/2	R	16	19	21	25	28	31	34	39	43	47	50	54	60
	L	102	117	131	155	176	195	212	242	269	293	316	337	376
4	R	17	20	22	26	30	33	36	41	46	50	54	57	64
	L	109	126	140	166	188	208	226	259	288	314	338	361	402

Coiled Expansion Loops and Offsets



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8.5.11 Pressure-Temperature Ratings—Soldered/Brazed Joints

Joining Material[4]	Service Temperature, °F	Fitting Type	Maximum Working Gage Pressure (psi), for Standard Water Tube Sizes[1] — Nominal of Standard Size, inches: 1/4 through 1	1 1/4 through 2	2 1/2 through 4	5 through 8	10 through 12
Alloy Sn50 50-50 Tin-Lead Solder[5]	100	Pressure[2]	200	175	150	135	100
		DWV[3]	—	95	80	70	—
	150	Pressure[2]	150	125	100	90	70
		DWV[3]	—	70	55	45	—
	200	Pressure[2]	100	90	75	70	50
		DWV[3]	—	50	40	35	—
	250	Pressure[2]	85	75	50	45	40
		DWV[3]	—	—	—	—	—
	Saturated Steam	Pressure	15	15	15	15	15
Alloy Sb5 95-5 Tin-Antimony Solder	100	Pressure[2]	1090	850	705	660	500
		DWV[3]	—	390	325	330	—
	150	Pressure[2]	625	485	405	375	285
		DWV[3]	—	225	185	190	—
	200	Pressure[2]	505	395	325	305	230
		DWV[3]	—	180	150	155	—
	250	Pressure[2]	270	210	175	165	125
		DWV[3]	—	95	80	80	—
	Saturated Steam	Pressure	15	15	15	15	15
Alloy E	100	Pressure[2]	710	555	460	430	325
		DWV[3]	—	255	210	215	—
	150	Pressure[2]	475	370	305	285	215
		DWV[3]	—	170	140	140	—
	200	Pressure[2]	375	290	240	225	170
		DWV[3]	—	135	110	115	—
	250	Pressure[2]	320	250	205	195	145
		DWV[3]	—	115	95	95	—
	Saturated Steam	Pressure	15	15	15	15	15
Alloy HB	100	Pressure[2]	1035	805	670	625	475
		DWV[3]	—	370	310	315	—
	150	Pressure[2]	710	555	460	430	325
		DWV[3]	—	255	210	215	—
	200	Pressure[2]	440	345	285	265	200
		DWV[3]	—	155	130	135	—
	250	Pressure[2]	430	335	275	260	195
		DWV[3]	—	155	125	130	—
	Saturated Steam	Pressure	15	15	15	15	15
Joining materials melting at or above 1100° F[6]	Pressure-temperature ratings consistent with the materials and procedures employed.						
	Saturated Steam	Pressure	120	120	120	120	120

NOTE: For extremely low working temperatures in the 0°F to minus 200°F range, it is recommended that a joint material melting at or above 1100°F be employed (see Note [6]).

[1] Standard water tube sizes per ASTM B 88.

[2] Ratings up to 8 inches in size are those given in ASME B16.22 *Wrought Copper and Copper Alloy Solder Joint Pressure Fittings* and ASME B16.18 *Cast Copper and Copper Alloy Solder Joint Fittings.* Rating for 10- to 12-inch sizes are those given in ASME B16.18 *Cast Copper and Copper Alloy Solder Joint Pressure Fittings.*

[3] Using ASME B16.29 *Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV*, and ASME B16.23 *Cast Copper Alloy Solder Joint Drainage Fittings — DWV.*

[4] Alloy designations are per ASTM B 32.

[5] The Safe Drinking Water Act Amendment of 1986 prohibits the use in potable water systems of any solder having a lead content in excess of 0.2%.

[6] These joining materials are defined as *brazing alloys* by the American Welding Society.

By permission, Copper Development Association.

8.5.12 Burst Pressures—Types K, L, M Copper Water Tubes

Actual Burst Pressures,[1] Types K, L, and M Copper Water Tube, psi at Room Temperature

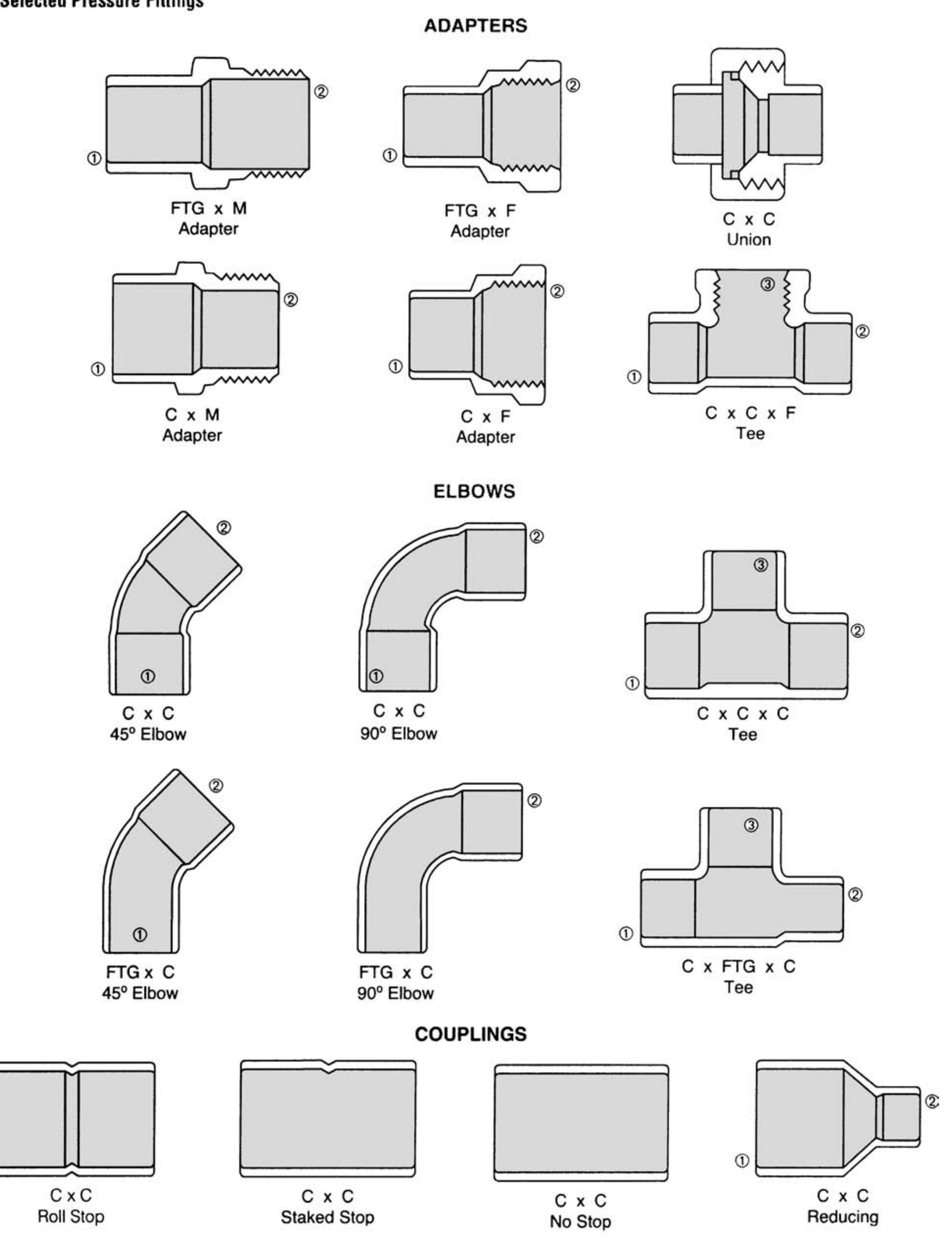
Nominal or Standard Size, inches	Actual Outside Diameter, in	K		L[2]		M	
		Drawn	Annealed	Drawn	Annealed	Drawn	Annealed
1/2	5/8	9840	4535	7765	3885	6135	—
3/4	7/8	9300	4200	5900	2935	4715	—
1	1 1/8	7200	3415	5115	2650	3865	—
1 1/4	1 3/8	5525	2800	4550	2400	3875	—
1 1/2	1 5/8	5000	2600	4100	2200	3550	—
2	2 1/8	3915	2235	3365	1910	2935	—
2 1/2	2 5/8	3575	—	3215	—	2800	—
3	3 1/8	3450	—	2865	—	2665	—
4	4 1/8	3415	—	2865	—	2215	—
5	5 1/8	3585	—	2985	—	2490	—
6	6 1/8	3425	—	2690	—	2000	—
8	8 1/8	3635	—	2650	—	2285	—

[1] The figures shown are averages of three certified tests performed on each type and size of water tube. In each case, wall thickness was at or near the minimum prescribed for each tube type. No burst pressure in any test deviated from the average by more than 5 percent.

[2] These burst pressures can be used for ACR tube of equivalent actual O.D. and wall thickness.

By permission, Copper Development Association.

8.6.0 Profiles of Selected Copper Fittings



By permission, Copper Development Association.

8.6.1 Recommended Procedures for Soldering Copper Fittings

SOLDERED JOINTS

The American Welding Society defines soldering as "a group of joining processes that produce coalescence of materials by heating them to a soldering temperature and by using a filler metal (solder) having a liquidus not exceeding 840°F and below the solidus of the base metals." In actual practice, most soldering is done at temperatures from about 350ºF to 600ºF.

To consistently make satisfactory joints, the following sequence of joint preparation and operations, based on ASTM Standard Practice B 828, should be followed:

- measuring and cutting
- reaming
- cleaning
- fluxing
- assembly and support
- heating
- applying the solder
- cooling and cleaning

The techniques described produce leak-tight soldered joints between copper and copper alloy tube and fittings, either in shop operations or in the field. Skill and knowledge are required to produce a satisfactorily soldered joint.

Measuring and Cutting

Accurately measure the length of each tube segment (**Figure 10**). Inaccuracy can compromise joint quality. If the tube is too short, it will not reach all the way into the cup of the fitting and a proper joint cannot be made. If the tube segment is too long, system strain may be introduced which could affect service life.

Cut the tube to the measured lengths. Cutting can be accomplished in a number of different ways to produce a satisfactory squared end. The tube can be cut with a disc-type tube cutter (**Figure 11**), a hacksaw, an abrasive wheel, or with a stationary or portable bandsaw. Care must be taken that the tube is not deformed while being cut. Regardless of method, the cut must be square to the run of the tube so that the tube will seat properly in the fitting cup.

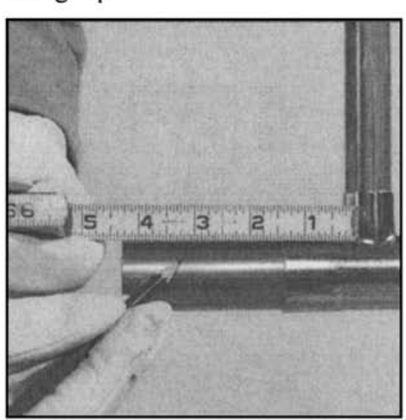


FIGURE 10: Measuring

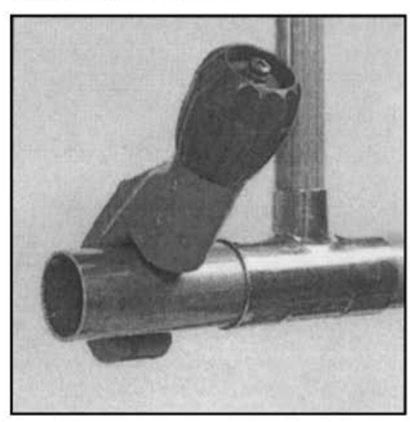


FIGURE 11: Cutting

Reaming

Ream all cut tube ends to the full inside diameter of the tube to remove the small burr created by the cutting operation. If this rough, inside edge is not removed by reaming, erosion-corrosion may occur due to local turbulence and increased local flow velocity in the tube. A properly reamed piece of tube provides a smooth surface for better flow.

Remove any burrs on the outside of the tube ends, created by the cutting operation, to ensure proper entrance of the tube into the fitting cup.

Tools used to ream tube ends include the reaming blade on the tube cutter, half-round or round files (**Figure 12**), a pocket knife (**Figure 13**), and a suitable deburring tool (**Figure 14**). With soft tube, care must be taken not to deform the tube end by applying too much pressure.

Soft temper tube, if deformed, can be brought back to roundness with a sizing tool. This tool consists of a plug and sizing ring.

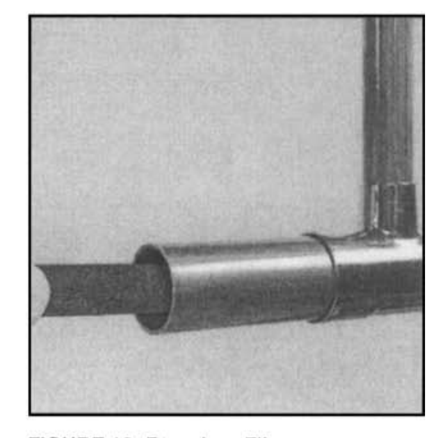


FIGURE 12: Reaming: File

By permission, Copper Development Association.

8.6.1 Recommended Procedures for Soldering Copper Fittings (Continued)

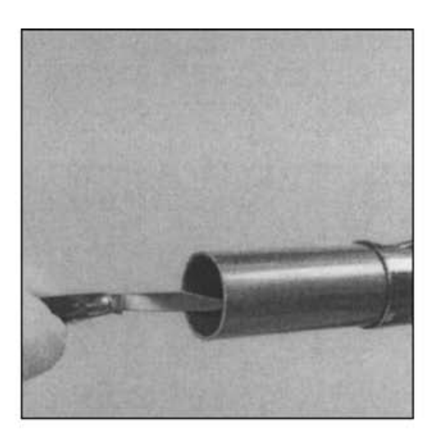


FIGURE 13: Reaming: Pocket Knife

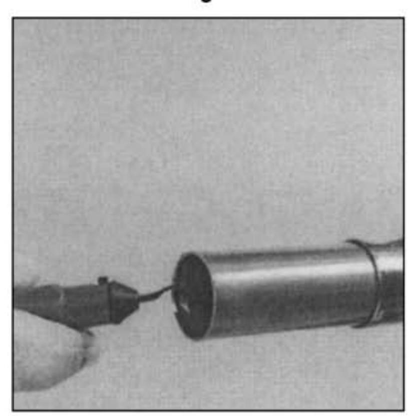


FIGURE 14: Reaming: Deburring Tool

Cleaning

The removal of all oxides and surface soil from the tube ends and fitting cups is crucial to proper flow of solder metal into the joint. Failure to remove them can interfere with capillary action and may lessen the strength of the joint and cause failure.

Lightly abrade (clean) the tube ends using sand cloth (**Figure 15**) or nylon abrasive pads (**Figure 16**) for a distance slightly more than the depth of the fitting cups.

Clean the fitting cups by using abrasive cloth, abrasive pads or a properly sized fitting brush (**Figure 17**).

The capillary space between tube and fitting is approximately 0.004 in. Solder metal fills this gap by capillary action. This spacing is critical for the solder metal to flow into the gap and form a strong joint.

Copper is a relatively soft metal. If too much material is removed from the tube end or fitting cup, a loose fit may result in a poor joint.

Chemical cleaning may be used if the tube ends and fittings are thoroughly rinsed after cleaning according to the procedure furnished by the cleaner manufacturer. Do not touch the cleaned surface with bare hands or oily gloves. Skin oils, lubricating oils and grease impair the soldering operation.

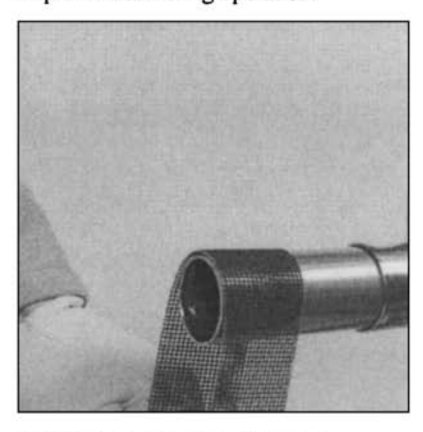


FIGURE 15: Cleaning: Sand Cloth

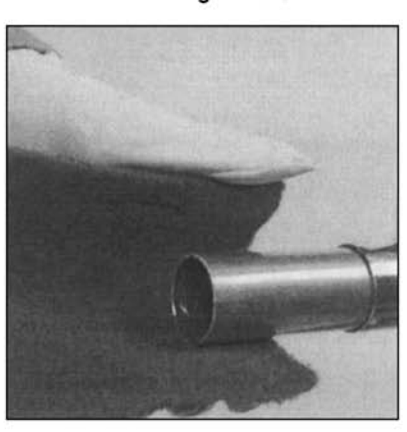


FIGURE 16: Cleaning: Abrasive Pad

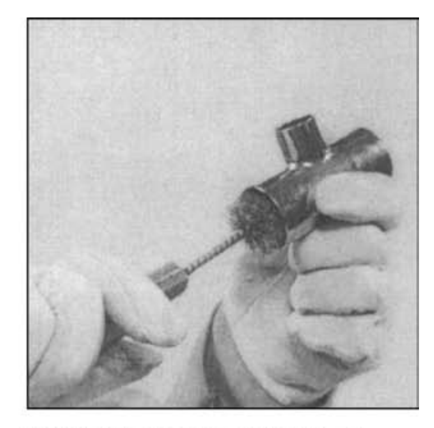


FIGURE 17: Cleaning: Fitting Brush

Applying Flux

Use a flux that will dissolve and remove traces of oxide from the cleaned surfaces to be joined, protect the cleaned surfaces from reoxidation during heating, and promote wetting of the surfaces by the solder metal, as recommended in the general requirements of ASTM B 813. Apply a thin even coating of flux with a brush to both tube and fitting as soon as possible after cleaning (**Figures 18** and **19**).

WARNING: Do not apply with fingers. Chemicals in the flux can be harmful if carried to the eyes, mouth or open cuts.

Use care in applying flux. Careless workmanship can cause problems long after the system has been installed. If excessive amounts of flux are used, the flux residue can cause corrosion. In extreme cases, such flux corrosion could perforate the wall of the tube, fitting or both.

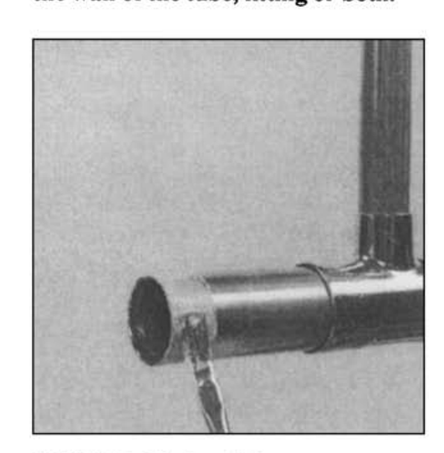


FIGURE 18: Fluxing: Tube

By permission, Copper Development Association.

8.6.1 Recommended Procedures for Soldering Copper Fittings (Continued)

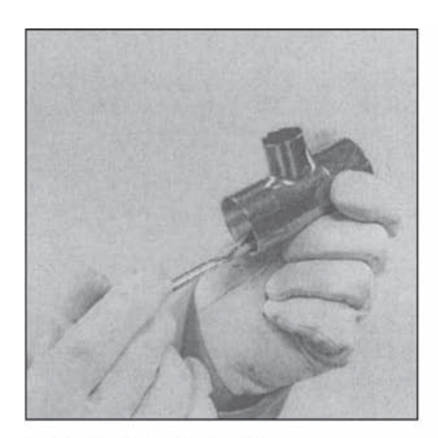


FIGURE 19: Fluxing: Fitting

Assembly and Support

Insert the tube end into fitting cup, making sure that the tube is seated against the base of the fitting cup (**Figure 20**). A slight twisting motion ensures even coverage by the flux. Remove excess flux from the exterior of the joint with a cotton rag (**Figure 21**).

Support the tube and fitting assembly to ensure a uniform capillary space around the entire circumference of the joint. Uniformity of capillary space will ensure good capillary flow, of the molten-solder metal. Excessive joint clearance can lead to solder metal cracking under conditions of stress or vibration.

The joint is now ready for soldering. Joints prepared and ready for soldering must be completed the same day and not left unfinished overnight.

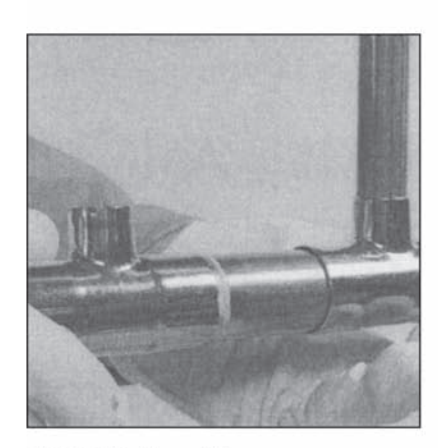


FIGURE 20: Assembly

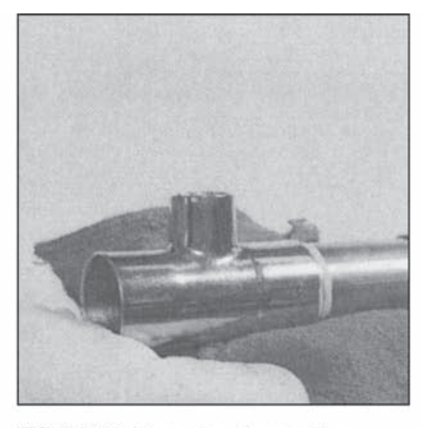


FIGURE 21: Removing Excess Flux

Heating

WARNING: When dealing with an open flame, high temperatures and flammable gases, safety precautions must be observed as described in ANSI/ASC Z49.1.

Begin heating with the flame perpendicular to the tube (**Figure 27,** position 1 and **Figure 22**). The copper tube conducts the initial heat into the fitting cup for even distribution of heat in the joint area. The extent of this preheating depends upon the size of the joint. Preheating of the assembly should include the entire circumference of the tube in order to bring the entire assembly up to a suitable preheat condition. However, for joints in the horizontal position, avoid directly preheating the top of the joint to avoid burning the soldering flux. The natural tendency for heat to rise will ensure adequate preheat of the top of the assembly. Experience will indicate the amount of heat and the time needed.

Next, move the flame onto the fitting cup (**Figure 27,** position 2 and **Figure 23**). Sweep the flame alternately between the fitting cup and the tube a distance equal to the depth of the fitting cup (**Figure 27,** position 3). Again, preheating the circumference of the assembly as described above, with the torch at the base of the fitting cup (**Figure 27,** postion 4), touch the solder to the joint. If the solder does not melt, remove it and continue heating.

CAUTION: Do not overheat the joint or direct the flame into the face of the fitting cup. Overheating could burn the flux, which will destroy its effectiveness and the solder will not enter the joint properly.

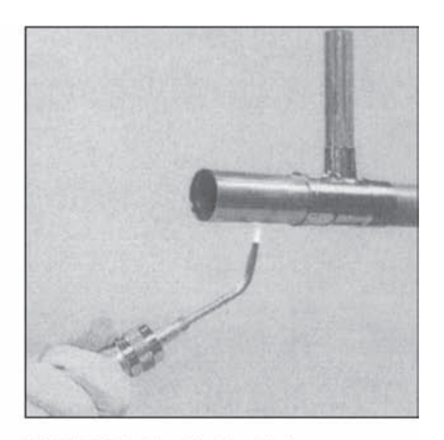


FIGURE 22: Pre-Heating Tube

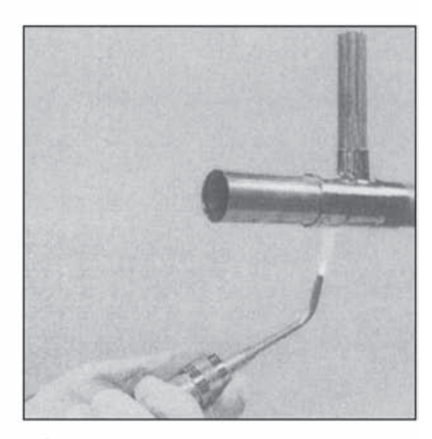


FIGURE 23: Pre-Heating Fitting

When the solder melts, apply heat to the base of the cup to aid capillary action in drawing the molten solder into the cup towards the heat source.

The heat is generally applied using an air-fuel torch. Such torches use acetylene or an LP gas. Electric resistance soldering tools can also be used (**Figure 24,** page 48). They employ heating electrodes and should be considered when an open flame is a concern.

Applying Solder

For joints in the horizontal position, start applying the solder metal slightly off-center at the bottom of the joint (**Figure 27,** position a, and **Figure 25**). When the solder begins to melt from the heat of the tube and fitting, push the solder straight into the joint while keeping the torch at

8.6.1 Recommended Procedures for Soldering Copper Fittings (Continued)

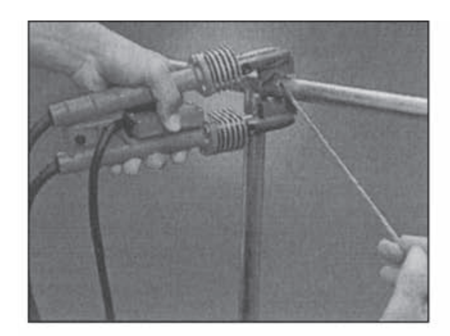


FIGURE 24: Electric Resistance Hand Tool

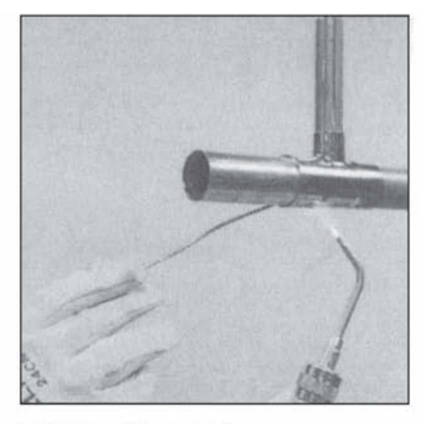


FIGURE 25: Soldering

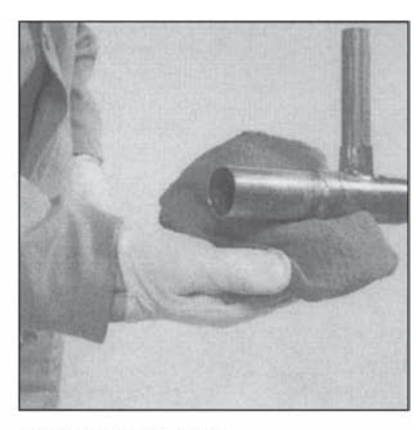


FIGURE 26: Cleaning

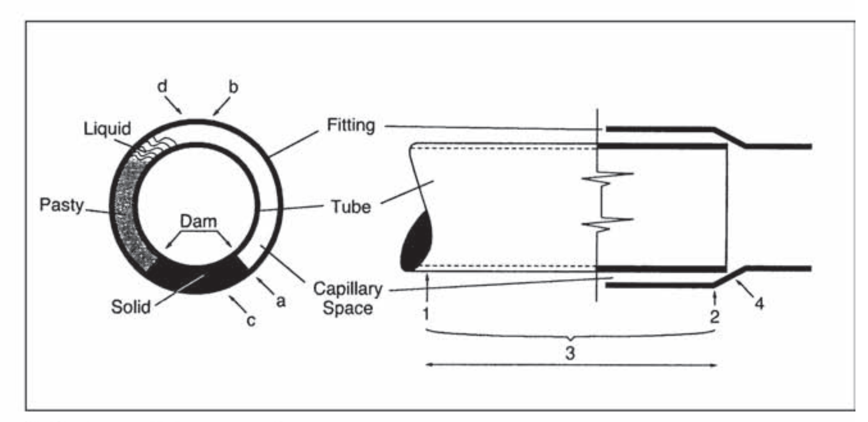


FIGURE 27: Schematic of Solder Joint

the base of the fitting and slightly ahead of the point of application of the solder. Continue this technique across the bottom of the fitting and up one side to the top of the fitting (**Figure 27,** postion b).

The now-solidified solder at the bottom of the joint has created an effective dam that will prevent the solder from running out of the joint as the side and top of the joint are being filled.

Return to the point of beginning, overlapping slightly (**Figure 27,** position c), and proceed up the uncompleted side to the top, again, overlapping slightly (**Figure 27,** position d). While soldering, small drops may appear behind the point of solder application, indicating the joint is full to that point and will take no more solder. Throughout this process you are using all three physical states of the solder: solid, pasty and liquid.

For joints in the vertical postion, make a similar sequence of overlapping passes starting wherever is convenient.

Solder joints depend on capillary action drawing free-flowing molten solder into the narrow clearance between the fitting and the tube. Molten solder metal is drawn into the joint by capillary action regardless of whether the solder flow is upward, downward or horizontal.

Capillary action is most effective when the space between surfaces to be joined is between 0.002 inch and 0.005 inch. A certain amount of looseness of fit can be tolerated, but too loose a fit can cause difficulties with larger size fittings.

For joining copper tube to solder-cup valves, follow the manufacturer's instructions. The valve should be in a partially open position before applying heat, and the heat should be applied primarily to the tube. Commercially available heat-sink materials can also be used for protection of temperature-sensitive components during the joining operation.

The amount of solder consumed when adequately filling the capillary space between the tube and either wrought or cast fittings may be estimated the flux requirement is usually 2 ounces per pound of solder.

Cooling and Cleaning

Allow the completed joint to cool naturally. Shock cooling with water may stress the joint. When cool, clean off any remaining flux residue with a wet rag (**Figure 26**). Whenever possible, based on end use, completed systems should be flushed to remove excess flux and debris.

Testing

Test all completed assemblies for joint integrity. Follow the testing procedure prescribed by applicable codes governing the intended service.

8.6.2 Galvanic (Dissimilar Metals) Corrosion Explained

Galvanic corrosion is created by self-induced current caused by the electrical potential of two dissimilar metals in contact with an electrolyte. For galvanic corrosion to take place, these two dissimilar metals must be connected in the presence of an electrolyte such as saltwater and acid solutions which are strong electrolytes. Fresh potable water is a weak electrolyte; steam does not act as an electrolyte. The weaker the electrolyte, the more limited will be any galvanic action.

The galvanic series of metals is divided into "most noble" and "least noble." The least noble metals are those that are corroded when joined to metals higher on the scale, they are electronegative. Metals closer to the most noble are cathodic and electropositive, which protects them from corrosion. Those metals listed here are only those commonly used in piping systems.

- *Least noble*. In increasing scale from least noble to most noble are zinc, galvanized steel or iron, aluminum, steel, iron, cast iron.
- *Most noble*. In increasing scale from least noble to most noble are lead, tin, brasses, copper bronzes, copper metal alloys, monel.

As an example, copper water pipe connected to steel pipe will cause the steel pipe to corrode because it is electronegative. When copper pipe or tubing is connected to some other piping material, if and when galvanic corrosion takes places, the other material is generally attacked and the copper pipe or tubing is protected.

To lessen the chance of galvanic corrosion, there are couplings available which are referred to as dialectric that insulate and break the electrical contact, thereby preventing this galvanic action.

8.7.0 Fiberglass Pipe Insulation—R-Values

This self-jacketed insulation can provide an R value of 4.35 per inch thickness and is effective on hot, cold, concealed, or exposed piping in temperature ranges of 0°F (–18°C) to 850°F (454°C). This type of insulation is highly cost-effective.

8.7.1 Calcium Silicate Pipe Insulation—Uses

This is a molded high-temperature, abuse-resistant pipe insulation, made from hydrous calcium silicate. This is the preferred insulation in the petrochemical and power generation industries owing to its resistance to breakage and abuse and its ability to withstand high temperatures up to 1200°F (649°C).

8.7.2 Polyisocyanurate Pipe Insulation—Uses

This closed-cell, high-performance insulation is available in a wide range of densities and compressive strengths for chilled water, tank and vessel, factory panelized construction modules, and, in sheet form, roof insulation. Polyisocyanurate is effective in very low temperatures of –297°F (–183°C) to 300°F (148°C).

8.7.3 Foamglass Pipe Insulation—Availability and Uses

This insulation is available in pipe or block form and is composed of millions of completed enclosed cells, each one of which offers insulation. Widely used for process piping and other equipment in the petrochemical and specialty chemical industries, it is also used in above- and below-grade steam and chilled water lines. This insulation is effective, and stable, for pipe and vessel installation with a wide range of temperatures, from –450°F (–268°C) to 900°F (482°C)

8.7.4 Mineral Wool Pipe Insulation—Composition and Uses

This insulation is comprised of basalt rock and steel slag, and it is noncombustible and highly thermally efficient. This type of insulation is molded and can easily be cut with a knife or handsaw. Efficiently operating within temperatures ranging up to 2150°F (1177°C), mineral wood insulation is used in power and process piping systems, has good compressive strength, and generates some dust when cut.

8.7.5 Armaflex Pipe Insulation

This flexible, elastomeric foam-type insulation is frequently used on chilled water and refrigeration systems and has excellent heat-retarding capability. It has superior condensation control and is effective in very low temperature applications of –297°F (–183°C) on up to 220°F (105°C).

8.7.6 Styrofoam Pipe Insulation—Used Primarily in Cold-Service Applications

Used primarily in cold-service applications, this closed-cell, extruded polystyrene insulation has excellent resistance to water and water absorption. Highly resistant to mold and mildew, Styrofoam insulation is manufactured in sheets, blocks, and premolded common pipe sizes. This insulation is low-cost, has long life, does not wick water, and has good thermal efficiency.

8.7.7 Polyethylene Pipe Insulation—A Closed-Cell Insulation

This is a closed-cell polyethylene insulation with self-seal qualities, available in preglued seams. This insulation has low VOC content, is fiber-free and dust-free, resists mold and mildew, and does not contain formaldehyde. Polyethylene pipe insulation is used on heating and plumbing piping in a temperature range from 0°F (–17°C) to 180°F (82°C).

8.8.0 Plastic Piping

Plastic piping is lightweight, corrosion-resistant, andresistant to many chemicals; it has low thermal conductivity and provides optimum flow characteristics. The range of products and applications is wide and somewhat varied.

8.8.0.1 Plastic Piping Material in Plumbing Applications



Pipe Reference Guide

(Updated October 2008)

Product	Sizes Available																				
	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	4 1/2	5	6	6 1/4	8	10	12	14	15	16
CPVC Schedule 80	●	●	●	●	●	●	●	●	●	●	●			●		●					
ChemDrain® CPVC Schedule 40 ★							●	●		●	●			●		●					
FlowGuard Gold® CPVC CTS SDR 11			●	●	●	●	●	●													
PVC Schedule 80	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●		●
PVC Schedule 40			●	●	●	●	●	●	●	●	●		●	●		●	●	●	●		●
PVC Schedule 40 DWV ★						●	●	●	●	●	●		●	●		●	●	●	●		●
PVC Schedule 30										●											
PVC DWV Foam Core ★							●	●		●	●			●		●	●	●			
PVC Well Casing								●	●	●	●	●		●	●	●					
PVC SDR 13.5 (PR315)			●																		
PVC SDR 21 (PR200)				●	●	●	●	●													
PVC SDR 26 (PR160)						●	●	●		●											
PVC SDR 35 Sewer Main Belled-End ★											●			●							
PVC SDR 35 Sewer Main Gasketed ★											●			●		●	●	●		●	
PVC Foam Core Sewer Main PS-50 Belled-End ★											●			●							
ABS DWV Foam Core ★							●	●		●	●			●							

★ Non-Pressure

Notes:

1. End treatments are Plain and Belled. Consult factory for availability.
2. Lengths are 10 and 20 feet (13 and 20 feet for gasketed sewer main). Consult factory for availability and non-standard lengths.
3. PVC Schedule 40 Bell End and PVC Well Casing pipe lengths for sizes 4", 4 1/2", 6", 6 1/4", and 8" are 20 feet plus the bell (20 foot laying length).
4. PVC SDR 35 Sewer Main Pipe in 13 foot lengths are 13 feet plus the bell (13 foot laying length).

By permission, Plastic Pipe and Fittings Association (PPFA).

8.8.0.2 Wall Thickness—Schedule 40 and 80 PVC and CPVC Pipe

Superior Quality Piping for a Wide Range of Applications

SCHEDULE 40 & 80 - DIMENSIONS

Schedule 40 Dimensions

Nom. Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P. PSI**
1/8"	0.405	0.249	0.068	0.051	810
1/4"	0.540	0.344	0.088	0.086	780
3/8"	0.675	0.473	0.091	0.115	620
1/2"	0.840	0.602	0.109	0.170	600
3/4"	1.050	0.804	0.113	0.226	480
1"	1.315	1.029	0.133	0.333	450
1-1/4"	1.660	1.360	0.140	0.450	370
1-1/2"	1.900	1.590	0.145	0.537	330
2"	2.375	2.047	0.154	0.720	280
2-1/2"	2.875	2.445	0.203	1.136	300
3"	3.500	3.042	0.216	1.488	260
3-1/2"	4.000	3.521	0.226	1.789	240
4"	4.500	3.998	0.237	2.118	220
5"	5.563	5.016	0.258	2.874	190
6"	6.625	6.031	0.280	3.733	180
8"	8.625	7.942	0.322	5.619	160
10"	10.750	9.976	0.365	7.966	140
12"	12.750	11.889	0.406	10.534	130
14"	14.000	13.073	0.437	12.462	130
16"	16.000	14.940	0.500	16.286	130
18"	18.000	16.809	0.562	20.587	130
20"	20.000	18.743	0.593	24.183	120
24"	24.000	22.544	0.687	33.652	120

Schedule 80 Dimensions

Nom. Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P. PSI**
1/8"	.405	.195	0.095	0.063	1230
1/4"	.540	.282	0.119	0.105	1130
3/8"	.675	.403	0.126	0.146	920

By permission, Harvel Plastics, Inc., Easton, PA.

8.8.0.2 Wall Thickness—Schedule 40 and 80 PVC and CPVC Pipe (Continued)

For Superior Corrosion Resistance in High Temperature Applications

SCHEDULE 80 - DIMENSIONS

Nom. Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P. PSI**
1/4"	.540	.282	0.119	0.117	1130
3/8"	.675	.403	0.126	0.162	920
1/2"	.840	.526	0.147	0.238	850
3/4"	1.050	.722	0.154	0.322	690
1"	1.315	.936	0.179	0.473	630
1-1/4"	1.660	1.255	0.191	0.654	520
1-1/2"	1.900	1.476	0.200	0.793	470
2"	2.375	1.913	0.218	1.097	400
2-1/2"	2.875	2.290	0.276	1.674	420
3"	3.500	2.864	0.300	2.242	370
3-1/2"	4.000	3.326	0.318	2.735	350
4"	4.500	3.786	0.337	3.277	320
5"	5.563	4.768	.375	4.078	290
6"	6.625	5.709	0.432	6.258	280
8"	8.625	7.565	0.500	9.506	250
10"	10.750	9.493	0.593	14.095	230
12"	12.750	11.294	0.687	19.392	230
14"	14.000	12.410	0.750	23.261	220
16"	16.000	14.213	0.843	29.891	220
18"	18.000	16.014	0.937	35.419	220
20"	20.000	17.814	1.031	45.879	220
24"	24.000	21.418	1.218	64.959	210

By permission, Harvel Plastics, Inc., Easton, PA.

8.8.0.2 Wall Thickness—Schedule 40 and 80 PVC and CPVC Pipe (Continued)

Nom. Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P. PSI**
1/4"	0.540	0.344	0.088	0.096	780
3/8"	0.675	0.473	0.091	0.128	620
1/2"	0.840	0.602	0.109	0.190	600
3/4"	1.050	0.804	0.113	0.253	480
1"	1.315	1.029	0.133	0.371	450
1-1/4"	1.660	1.360	0.140	0.502	370
1-1/2"	1.900	1.590	0.145	0.599	330
2"	2.375	2.047	0.154	0.803	280
2-1/2"	2.875	2.445	0.203	1.267	300
3"	3.500	3.042	0.216	1.660	260
3-1/2"	4.000	3.521	0.226	1.996	240
4"	4.500	3.998	0.237	2.363	220
6"	6.625	6.031	0.280	4.164	180
8"	8.625	7.942	0.322	6.268	160
10"	10.750	9.976	0.365	8.886	140
12"	12.750	11.889	0.406	11.751	130
14"	14.000	13.073	0.437	13.916	130
16"	16.000	14.940	0.500	18.167	130
18"	18.000	16.809	0.562	22.965	130
20"	20.000	18.743	0.593	29.976	120
24"	24.000	22.544	0.687	37.539	120

Schedule 80

Nom. Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nom. Wt./Ft.	Max. W.P. PSI**
1/4"	.540	.282	0.119	0.117	1130
3/8"	.675	.403	0.126	0.162	920
1/2"	.840	.526	0.147	0.238	850
3/4"	1.050	.722	0.154	0.322	690
1"	1.315	.936	0.179	0.473	630
1-1/4"	1.660	1.255	0.191	0.654	520
1-1/2"	1.900	1.476	0.200	0.793	470
2"	2.375	1.913	0.218	1.097	400
2-1/2"	2.875	2.290	0.276	1.674	420
3"	3.500	2.864	0.300	2.242	370
3-1/2"	4.000	3.326	0.318	2.735	350
4"	4.500	3.786	0.337	3.277	320
6"	6.625	5.709	0.432	6.258	280
8"	8.625	7.565	0.500	9.506	250
10"	10.750	9.493	0.593	14.095	230
12"	12.750	11.294	0.687	19.392	230
14"	14.000	12.410	0.750	23.261	220
16"	16.000	14.213	0.843	29.891	220
18"	18.000	16.014	0.937	35.419	220
20"	20.000	17.814	1.031	45.879	220

By permission, Harvel Plastics, Inc., Easton, PA.

8.8.0.2 Wall Thickness—Schedule 40 and 80 PVC and CPVC Pipe (Continued)

3/8"	.675	.403	0.126	0.146	920
1/2"	.840	.526	0.147	0.213	850
3/4"	1.050	.722	0.154	0.289	690
1"	1.315	.936	0.179	0.424	630
1-1/4"	1.660	1.255	0.191	0.586	520
1-1/2"	1.900	1.476	0.200	0.711	470
2"	2.375	1.913	0.218	0.984	400
2-1/2"	2.875	2.290	0.276	1.500	420
3"	3.500	2.864	0.300	2.010	370
3-1/2"	4.000	3.326	0.318	2.452	350
4"	4.500	3.786	0.337	2.938	320
5"	5.563	4.768	0.375	4.078	290
6"	6.625	5.709	0.432	5.610	280
8"	8.625	7.565	0.500	8.522	250
10"	10.750	9.493	0.593	12.635	230
12"	12.750	11.294	0.687	17.384	230
14"	14.000	12.410	0.750	20.852	220
16"	16.000	14.213	0.843	26.810	220
18"	18.000	16.014	0.937	33.544	220
20"	20.000	17.814	1.031	41.047	220
24"	24.000	21.418	1.218	58.233	210

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8.8.0.3 Physical Properties—ABS and PVC Pipe

PHYSICAL PROPERTIES OF ABS AND PVC MATERIALS

Plastics Technical Manual

PROPERTY	UNITS	ABS	ASTM NO.	PVC	ASTM NO.
Specific Gravity	g/cc	1.05	D 792	1.40	D 792
Tensile Strength (73°F) Minimum	Psi	4,500	D 638	7,000	D 638
Modulus of Elasticity in Tension (73°F) Minimum	Psi	240,000	D 638	400,000	D 638
Flexural Strength (73°F)	Psi	10,585	D 790	14,000	D 790
Izod Impact (notched at 73°F) Minimum	ft lb/ in.	6.00	D 256	0.65	D 256
Hardness (Durometer D)		70	D 2240	80 ± 3	D 2240
Hardness (Rockwell R)		100	D 785	110 - 120	D 785
Compressive Strength (73°F)	Psi	7,000	D 695	9,600	D 695
Hydrostatic Design Stress	Psi	N/A		2,000	D 1598
Coefficient of Linear Expansion	in./ in./ °F	5.5×10^{-5}	D 696	3.0×10^{-5}	D 696
Heat Distortion Temperature at 264 psi Minimum	°F	180	D 648	160	D 648
Coefficient of Thermal Conductivity	BTU/ hr/sq ft/ °F/ in.	1.1	C 177	1.2	C 177
Specific Heat	BTU/ °F/lb	0.35	D 2766	0.25	D 2766
Water Absorption (24 hrs at 73°F)	% weight gain	0.40	D 570	.05	D 570
Cell Classification - Pipe		42222	D 3965	12454	D 1784
Cell Classification - Fittings		32222	D 3965	12454	D 1784
Burning Rate				Self Ext.	D 635
Burning Class				V-0	UL 94*

Above data is based upon information provided by the raw material manufacturers. It should be used only as a recommendation and not as a guarantee of performance. * Underwriters Laboratories standard

ABS and PVC Standards

TYPE PIPE / FITTING	STANDARD SPECIFICATIONS	
	MATERIAL	DIMENSIONS
ABS DWV		
Schedule 40 DWV Foam Core Pipe	ASTM D 3965	ASTM F 628
Schedule 40 DWV Fittings	ASTM D 3965	ASTM D 2661
PVC DWV		
Schedule 40 DWV Pipe	ASTM D 1784	ASTM D 2665 & ASTM D 1785
Schedule 40 DWV Foam Core Pipe	ASTM D 4396	ASTM F 891
Schedule 40 DWV Fittings	ASTM D 1784	ASTM D 2665
PVC Pressure		
Schedule 40 Plain End Pipe	ASTM D 1784	ASTM D 1785
Schedule 40 Bell End Pipe	ASTM D 1784	ASTM D 1785
Schedule 40 Bell End Well Casing	ASTM D 1784	ASTM D 1785 & ASTM F 480
SDR 21 (PR 200) Bell End Pipe	ASTM D 1784	ASTM D 2241
SDR 26 (PR 160) Bell End Pipe	ASTM D 1784	ASTM D 2241
Schedule 40 Fittings	ASTM D 1784	ASTM D 2466
Schedule 80 Plain End Pipe	ASTM D 1784	ASTM D 1785
Schedule 80 Fittings	ASTM D 1784	ASTM D 2464 & ASTM D 2467

By permission, Plastic Pipe and Fittings Association (PPFA).

8.8.0.4 Plastic Pipe Pressure Ratings—ABS, PVC, PE Pipe

Plastic Pipe Pressure Ratings @ 73° F (psi)

Pipe Size (in)	ABS 1316 (D 1527)		PVC 1120 (D 1785)		PE 3408 (D 2447)	
	Sch 40	Sch 80	Sch 40	Sch 80	Sch 40	Sch 80
½	480	680	600	850	240	340
¾	390	550	480	690	195	275
1	360	500	450	630	180	250
1¼	290	420	370	520	145	210
1½	260	380	330	470	130	190
2	220	320	280	400	110	160
2½	240	340	300	420	120	170
3	210	300	260	370	105	150
3½	190	280	240	350	95	140
4	180	260	220	320	90	130
5	160	230	190	290	80	115
6	140	220	180	280	70	110
8	120	200	160	250	60	100
10	110	190	140	230	55	95
12	110	180	130	230	55	90

Note that the above values are for unthreaded pipe. Threading pipe reduces pressure ratings and may not be allowed for some materials. See the individual material lessons for more information.

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8.8.0.5 Pressure/Temperature Applications for ABS, PE, and PVC Pipe

Uses of Plastic Pipe

Pressure applications

PRESSURE APPLICATIONS
Plastic pressure piping is used for many industrial processes, in heating and cooling systems, fire protection installations, gas distribution, and for water supply and distribution.

Potable water applications include cold water services from wells or water mains up to the building as well as hot and cold water distribution piping within buildings.

ABS, PE and PVC materials are all available with 73°F stress rating for use in pressure piping. PE piping is used extensively for cold water service lines and water distribution systems outside the building. Its low temperature flexibility make it especially suited for use in applications where temperature of 35°F and lower will occur.

The maximum temperature at which PE has an HDS rating is 140°F.

MATERIALS WITH HDS RATINGS FOR HIGHER TEMPERATURES
Chlorinated Poly (Vinyl Chloride) (CPVC), and cross-linked polyethylene (PEX) materials are available that are rated for long term service at 180°F as well as for cold water applications. Hot and cold water distribution system piping made from these materials has a working pressure rating of 100 psi at 180°F. These systems are tested at 150 psi at 210°F for at least 48 hours to assure integrity at those condition, which may develop in the event the water heater controls malfunction. Thus, such materials are suitable for hot water distribution where water heaters are installed with relief valves set at 150 psi, 210°F.

All plumbing codes require the use of piping having the 100 psi @ 180°F rating for both the hot and the cold water portions of the water distribution system.

Non-pressure applications

Besides offering low installed costs, plastic pipe is attractive for non-pressure applications (DWV and sewer) because the smooth inner walls assure high gravity flow rates and minimize the chances of developing stoppages. Plastic sewer pipes have adequate strength for earth loads and high chemical resistance, which means long life when used for sewer installations.

ABS, PVC and PE plastic pipe materials are used for these applications. There are separate ASTM standards for each plastic pipe based on material, dimensioning system, application, and (sometimes) sizing.

ABS and PVC piping have been used for many years in residential DWV systems where intermittent temperature excursions up to 180°F for ABS and 140°F for PVC can occur.

By permission, Plastic Pipe and Fittings Association (PPFA).

8.8.0.6 Plastic Pipe—Manufactured in Various Colors

Color alone should not be used to determine the proper application of plastic pipe—always identify the pipe by also checking the printing on the pipe.

- Gas distribution—yellow or black with yellow stripes
- Water distribution—black, light blue, white, clear or gray
- Sewer—green, white, black or gray
- Drain, waste, and vents (DWV)—black, white, tan, or gray
- Hot/cold water distribution— tan, red, white, blue, silver, or clear
- Cable duct—variety of colors
- Fire sprinklers—orange
- Industrial process piping—dark gray for PVC, light gray for CPVC
- Reclaimed water—purple or brown (check with local authorities who may set special requirements)

8.8.0.7 ASTM Plastic Pipe Standards

PVC (Polyvinyl Chloride) Piping ASTM Standards

Product	ASTM Specification	Title
Pipe (1120, 1220, 2120)	D 1785	Poly (Vinyl Chloride) (PVC) Schedules 40, 80 and 120
Pipe (PVC 1120, 1220, 2120)	D 2241	Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
Fittings	D 2464	ThreadedPoly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
Fittings	D 2466	Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
Fittings	D 2467	Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
Solvent Cement	D 2564	Solvent Cement Systems for Poly (Vinyl Chloride) (PVC) Plastic Piping systems
Primer*	F 656*	Primers for Use in Solvent Cement Joints of Poly (Vinyl Chloride) (PVC) Plastic Pipe and fittings*

CPVC (Chlorinated Polyvinyl Chloride) ASTM Standards

Product	ASTM Specifications	Title
Pipe and Fittings	D 2846	Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems
Fittings	F437	Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe fittings, Schedule 80
Fittings	F439	Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80a
Pipe	F 441	Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
Solvent Cement	F 493	Solvent Cements for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
Primer*	F 656*	Primers for Use in Solvent Cement Joints of Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe and Fittings*

By permission, Plastic Pipe and Fittings Association (PPFA).

8.8.1 Polyvinyl Chloride (PVC)—Types and Uses

PVC piping is recognized as acceptable piping material for drain, waste, and vent (DWV) plumbing applications, sewer lines, water mains, and irrigation, and as electrical cable conduits. When used outdoors, it contains stabilizers and uv inhibitors to shield against ultraviolet radiation. These pipes are manufactured in both solid and cellular wall construction, the latter involving the simultaneous extrusion of at least three layers of material into the pipe wall.

8.8.2 Chlorinated Polyvinyl Chloride (CPVC)—Types and Uses

CPVC materials do not support combustion and as such can be used in fire sprinkler piping systems. This piping material is also suitable for hot and cold water distribution. CPVC is safe to use in return air plenums, when approved by local authorities, because it will not burn without a significant flame source. In diameters 3 inches (7.6 cm) or less, CPVC has passed the 25/50 flame smoke developed test requirements for nonmetallic material in return air plenums.

8.8.3 Acrylonitrile-Butadiene-Styrene (ABS)—Applications

ABS pipe finds application in drainage, waste, and vent piping systems. Because of its high resistance to fire [ABS must be heated to 871°F (465°C) before it will self-ignite], it also finds use in fire-rated wall floor and ceiling assemblies. When used outdoors, ABS will contain pigments to shield against ultraviolet radiation, or the pipe can be painted with a water-based latex paint to resist uv degradation.

8.8.4 Polyethylene (PE)—Uses

Polyethylene pipe is manufactured in sizes from ½ to 6 in. (1.27 to 15.2 cm). PE pipe is used for potable water service and distribution lines, natural gas distributions, sewage and waste disposal, and drainage lines. This pipe can also be used in low-temperature applications without the risk of brittle failure and also finds application in low-temperature heat piping such as radiant floor heating and snow melting.

8.8.5 Cross-Linked Polyethylene (PEX)—Applications

PEX is widely used in heat transfer applications such as low-temperature floor heating and snow melting and in distribution piping for hot water baseboard, convectors, and radiators where temperatures do not exceed 200°F (111°C). PEX tubing is also acceptable for water distribution piping, and when used for potable water, a laboratory or mark will be applied to the tubing indicating suitability for potable water.

8.8.6 Polybutylene (PB) Pipe—Limited Uses

PB pipe is a copolymer widely used in water piping systems in the mid-1990s. However, the pipe developed microcracks, and the average PB piping system began to leak 9 years after installation. It is no longer used, for obvious reasons. Any existing systems can be identified by the gray or silver color, the copper or silver colored bands that hold the joints together, and if used in underground service, it will be colored blue, gray, or black.

8.9.0 Plastic Pipe Installation Procedures

Plastic pipe installation can be accomplished in one of two methods—welds or mechanical means. The solvent weld joint procedures are shown in 8.9.0.1 and 8.9.0.2.

8.9.0.1 Sketch of Solvent Weld Joint before, after Assembly

JOINING METHODS

✓SOCKET WITH SOLVENT CEMENT

The most commonly used joining method for ABS pipe and fittings uses a solvent-cement on the pipe end and in the inside of the fitting socket. The pipe end and socket must be free of dirt, loose particles, or moisture. The ABS pipe and fitting are assembled after placing solvent cement on the outside of the pipe and the inside of the fitting cup immediately before inserting the pipe into the fitting socket.

The inside of the socket is made with a slight taper, with the diameter greater than the pipe OD at the open end of the socket to less than the OD of the pipe at the bottom of the socket. Thus, there is an interference between the outside diameter of the pipe and the inside of the socket approximately midway into the socket. The ***solvent***-cement permits the pipe and fitting material to flow sufficiently to allow the pipe to ***bottom*** in the socket, and a solid, substantial joint is formed as soon as the cement sets — usually a matter of one to two minutes (depending on conditions).

The solvent cement manufacturer's recommendations should be followed carefully in all details to produce a serviceable joint. Figures 4-B, 4-C, and 4-D show the joint as it is being assembled and completed. For additional information, see ASTM F 402, Standard Practices for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings.

The cement used to join plastic pipe and fittings consists of a solvent appropriate to the plastic being joined, and some of the same plastic type dissolved in the mix. Thus, there is no universal, or multi-purpose, plastic solvent cement possible. Each plastic piping material must use the correct solvent-cement for that type material.

Although some ***multi-purpose*** solvent cements are available, most pipe and fitting manufacturers do not recommend their use. Likewise, model plumbing codes do not permit such use.

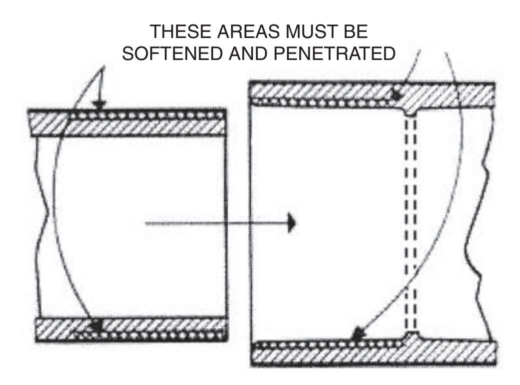


Figure 4-B: Cement coatings of sufficient thickness. Joint surfaces must be assembled while surfaces are wet and soft. Courtesy NIBCO, Inc.

By permission, Plastic Pipe and Fittings Association (PPFA).

8.9.0.1 Sketch of Solvent Weld Joint before, after Assembly (Continued)

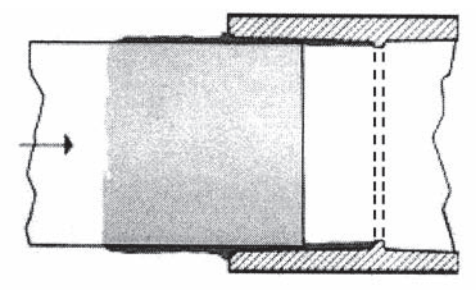


Figure 4-C: Solvent cement joint being assembled. Surfaces must be assembled while they are wet and soft. Courtesy NIBCO, Inc.

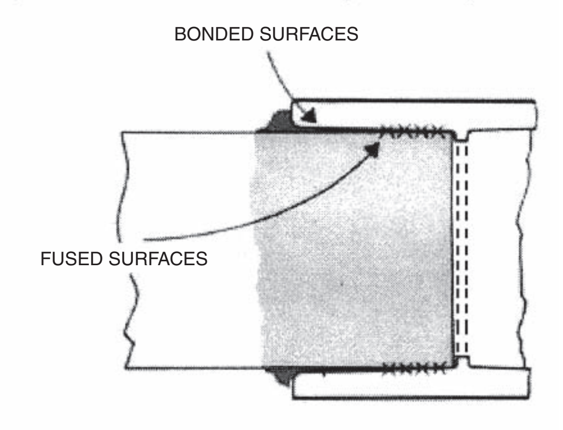


Figure 4-D: Completed solvent cement joint. Note bonded and fused surfaces. Courtesy NIBCO, Inc.

By permission, Plastic Pipe and Fittings Association (PPFA).

8.9.0.2 Seven Steps to Solvent Welding

INSTALLATION PROCEDURES

Installation Procedures for ABS, PVC and CPVC Piping Systems

With our reliable, easy-to-install ABS, PVC and CPVC TrueFit systems, Charlotte Pipe and Foundry is doing more than any other supplier to help contractors work more efficiently and productively.

The following information contains suggested installation and testing procedures and does not encompass all of the requirements for the design or installation of a piping system.

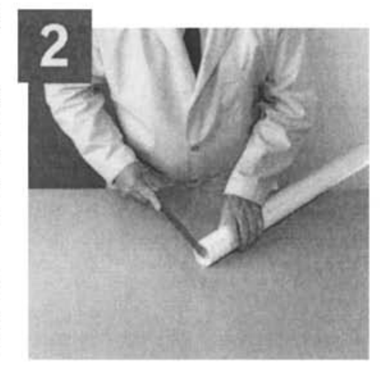
- Observe all safety precautions.
- Systems should be installed in a good and workmanlike manner consistent with normal industry standards and in conformance with all local plumbing, fire and building code requirements. Failure to follow proper installation practices, procedures, or techniques can result in system failure, property damage, or personal injury.
- Pipe and fitting systems should be used for their intended purpose as defined by local plumbing and building codes and the applicable ASTM standard.
- Follow manufacturers' instructions for all related products.

1. Cut Pipe

- Cut pipe square. As joints are sealed at the base of the fitting hub. An angled cut may result in joint failure.
- Acceptable tools include miter saw, mechanical cut off saw or wheel cutter. Wheel type cutters must employ a blade designed for plastics.

2. Remove Burr And Bevel

- Remove all pipe burr from inside and outside diameter of pipe with a knife-edge, file, or deburring tool.
- Chamfer (bevel) the end of the pipe 10°-15° as shown to the right.



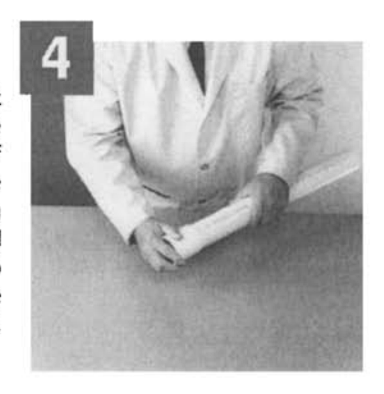
3. Clean and Dry Pipe and Fittings

- Remove surface dirt, grease, or moisture with a clean dry cloth.



4. Dry Fit

- With light pressure, pipe should go one half to one third of the way into the fitting hub. Pipe and fittings that are too tight or too loose should not be used.



5. Applicator

- Use an applicator that is one half the pipe diameter.
- Too large an applicator will force excessive cement into the inside of small diameter fittings. Too small an applicator will not apply sufficient cement to large diameter systems.





By permission, Plastic Pipe and Fittings Association (PPFA).

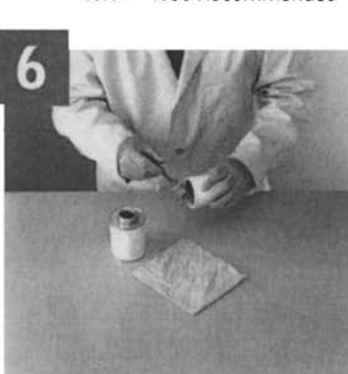
8.9.0.2 Seven Steps to Solvent Welding (Continued)

INSTALLATION PROCEDURES

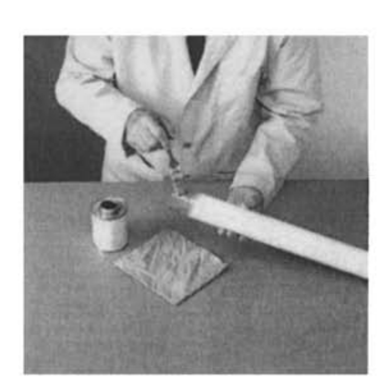
Nominal Pipe Size (in.)	Applicator Type		
	Dauber	Brush Width (in.)	Roller Length (in.)
1/4	A	1/2	NR
3/8	A	1/2	NR
1/2	A	1/2	NR
3/4	A	1	NR
1	A	1	NR
1 1/4	A	1	NR
1 1/2	A	1 - 1 1/2	NR
2	A	1 - 1 1/2	NR
2 1/2	NR	1 1/2 - 2	NR
3	NR	1 1/2 - 2 1/2	NR
4	NR	2 - 3	3
5	NR	3 - 5	3
6	NR	3 - 5	3
8	NR	4 - 6	7
10	NR	6 - 8	7
12	NR	6 - 8	7
14	NR	7 - 8	7
16	NR	8+	8

A = Acceptable NR = Not Recommended

6. Coat Surfaces with Primer and Cement



- Apply primer to PVC and CPVC pipe and fitting surfaces. Do not allow primer to puddle inside the system. Primer should conform to ASTM F 656.The use of primer for ABS is not recommended.
- Apply a full even layer of cement on the pipe O.D. for a distance slightly greater than the depth of the socket of the fitting.



- Coat the fitting socket with a medium layer of cement, avoiding puddling inside the system. Apply a second full even layer of cement on the pipe O.D. Solvent cement should meet ASTM D 2564 for PVC systems, ASTM F 493 for CPVC systems, and ASTM D 2235 for ABS systems.

7. Join Pipe and Fittings



- Assemble pipe and fittings quickly while cement is fluid.
- Insert pipe into fitting hub until it contacts socket bottom. Give pipe a quarter turn. Hold pipe and fitting together until the pipe does not back out.
- See table for recommended cure times.
- Remove excessive cement from the exterior. A properly made joint will show a continuous bead of cement around the perimeter.

Threaded Joint

When combining plastic and metal threaded systems, it is recommended that plastic male threads be screwed into metal female threads rather than metal male threads into plastic female threads.

By permission, Plastic Pipe and Fittings Association (PPFA).

8.9.1 Joining Techniques for Plastic Piping

ABS, CPVC, and PVC pipes are commonly joined by solvent cementing; however, mechanical joints are also available. PE, PEX, and PP pipe cannot be joined with solvent cement but use mechanical fitting joining.

8.9.1.1 Joint Types and Curing Times for ABS, PVC, CPVC Pipes

- *Heat fusion attachment*. Both ends of the pipe or tube are heated to a required temperature in a special heating device, and the ends are quickly pushed over the fitting. This joining method is used on PE, PP, and PVDF pipe. There are four types of heat fusion joints: butt fusion, socket fusion, electrofusion, and saddle fusion. Socket and saddle fusion are similar to butt fusion. In the electrofusion process, the required temperature and heating time are controlled by passing current through an electrical resistance wire embedded in the socket. Butt fusion is made by "butting" the two pieces of pipe together, securely fastening them, and melting the pipe interfaces with a special machine.
- *Mechanical fitting joining*. There are three basic types of mechanical fittings for PE, PEX, and PP piping.
  1. *Crimp ring type.* A crimp ring encloses the tube, and an insert is compressed by a special tool after assembly. This crimp ring joint cannot be reused, and once it is in place, it will remain there until cut out of the pipe.
  2. *Nut ferrule type*. A threaded nut is tightened onto a machined thread and compresses the tube or a ferrule over the inserted part and then is made up tight. This fitting can be taken apart and reassembled.
  3. *Stab type*. The end of the tube or pipe is cut and chamfered, and the fitting is "stabbed" into the tube or pipe.

8.9.1.1 Joint Types and Curing Times for ABS, PVC, CPVC Pipes (Continued)

JOINT CURING

Joint Curing

The joint should not be disturbed until it has initially set. The chart below shows the recommended initial set times.

Recommended Initial Set Times

Temperature Range	Pipe Sizes ½" to 1¼"	Pipe Sizes 1½" to 3"	Pipe Sizes 4" to 8"	Pipe Sizes 10" to 16"
60° - 100° F	15 min	30 min	1 hr	2 hr
40° - 60° F	1 hr	2 hr	4 hr	8 hr
0° - 40° F	3 hr	6 hr	12 hr	24 hr

The joint should not be pressure tested until it has cured. The exact curing time varies with temperature, humidity, and pipe size. The following chart shows suggested curing times.

Recommended Curing Time Before Pressure Testing

RELATIVE HUMIDITY 60% or Less*	CURE TIME Pipe Sizes ½" to 1¼"		CURE TIME Pipe Sizes 1½" to 3"		CURE TIME Pipe Sizes 4" to 8"		CURE TIME Pipe Sizes 10" to 16"
Temperature Range During Assembly and Cure Periods	Up to 180 psi	Above 180 to 370 psi	Up to 180 psi	Above 180 to 315 psi	Up to 180 psi	Above 180 to 315 psi	Up to 100 psi
60° - 100° F	1 hr	6 hr	2 hr	12 hr	6 hr	24 hr	24 hr
40° - 60° F	2 hr	12 hr	4 hr	24 hr	12 hr	48 hr	48 hr
0° - 40° F	8 hr	48 hr	16 hr	96 hr	48 hr	8 days	8 days

*For relative humidity above 60%, allow 50% more cure time.
The above data are based on laboratory tests and are intended as guidelines.
For more specific information, contact should be made with the cement manufacturer.

***Average number of joints per Quart for Cement and Primer (Source: IPS Weld-on)**

Pipe Diameter	1/2"	3/4"	1"	1-1/2"	2"	3"	4"	6"	8"	10"	12"	15"	18"
Number of Joints	300	200	125	90	60	40	30	10	5	2 to 3	1 to 2	3/4	1/2

For Primer: double the number of joints shown for cement.
* These figures are estimates based on IPS Weld-on laboratory tests.
Due to many variables in the field, these figures should be used as a general guide only.

Testing Pressure System

1. Prior to testing, safety precautions should be instituted to protect personnel and property in case of test failure.
2. Conduct pressure testing with water. DO NOT USE AIR OR OTHER GASES for pressure testing.
3. The piping system should be adequately anchored to limit movement. Water under pressure exerts thrust forces in piping systems. Thrust blocking should be provided at changes of direction, change in size and at dead ends.
4. The piping system should be slowly filled with water, taking care to prevent surge and air entrapment. The flow velocity should not exceed 5 feet per second (see charts on pages 37-41).
5. All trapped air must be slowly released. Vents must be provided at all high points of the piping system. All valves and air relief mechanisms should be opened so that the air can be vented while the system is being filled. Trapped air is extremely dangerous and it must be slowly and completely vented prior to testing.
6. Once an installation is completed and cured the system should be filled with water and pressure tested in accordance with local code requirements. However, care must be taken to ensure the pressure does not exceed the working pressure of the lowest component in the system (valves, unions, flanges, threaded parts, etc.)
7. The pressure test should not exceed one hour. Any leaking joints or pipe must be cut out and replaced and the line recharged and retested using the same procedure.

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8.9.2 Expansion and Contraction Characteristics of Plastic Materials

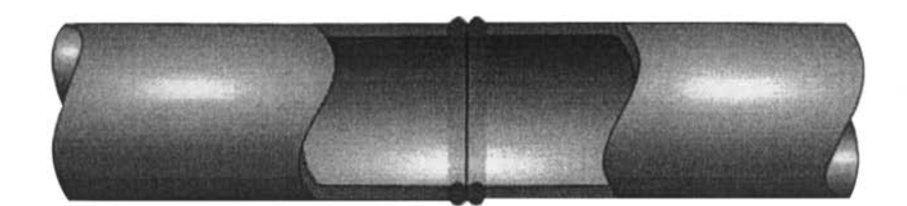
Plastic materials have a greater coefficient of expansion than metals, and in plastic pipe installations where significant temperature change is anticipated, piping dimensional changes can be compensated by piping offsets or loops and by the use of expansion joints.

8.9.2.1 Butt Fusion Joints

The principle of heat fusion is to heat two surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion. When fused according to the pipe and/or fitting manufacturers' procedures, the joint area becomes as strong as or stronger than the pipe itself in both tensile and pressure properties. As soon as the joint cools to near ambient temperature, it is ready for handling. The following sections of this chapter provide a general procedural guideline for each of these heat fusion methods.

NOTE: This is a general discussion. Pipe and fitting manufacturers have established qualified fusion procedures[9] which should be followed precisely when using their specific products.

One method, used for all three types of joints, uses special heating tools for heating the parts to be joined. The other method, 'electrofusion', is used only for socket and saddle-type joints. Heat is generated by inducing electric current into a wire coil that is a part of the fitting.



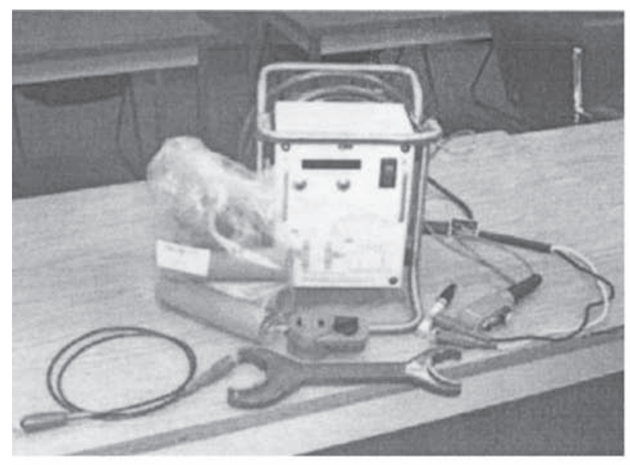
Butt Fusion

The most widely used method for joining individual lengths of large diameter polyethylene pipe is by heat fusion of the pipe butt ends as illustrated in Figure 6.1. This technique, which precludes the need for specially modified pipe ends or couplings, produces a permanent, economical and flow-efficient connection. Field-site butt fusions may be made readily by trained operators using specially developed butt fusion machines that secure and precisely align the pipe ends for the fusion process.

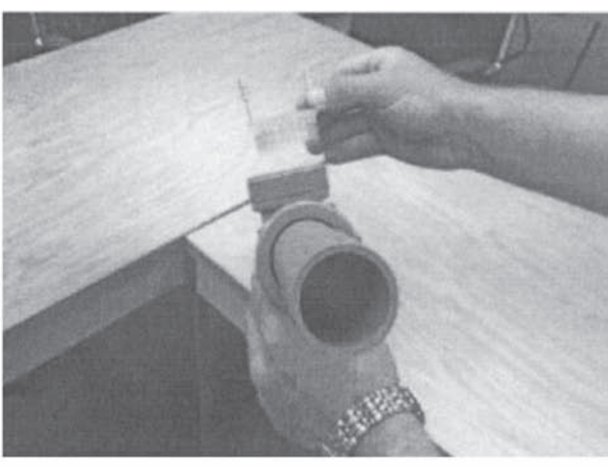
The six steps involved in making a butt fusion joint are:

1. Securely fasten the components to be joined
2. Face the pipe ends
3. Align the pipe profile
4. Melt the pipe interfaces
5. Join the two profiles together
6. Hold under pressure

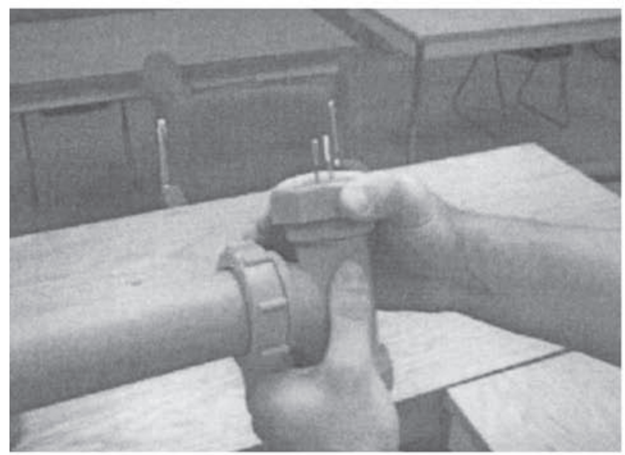
8.9.3 Electric Fusion Equipment, Techniques



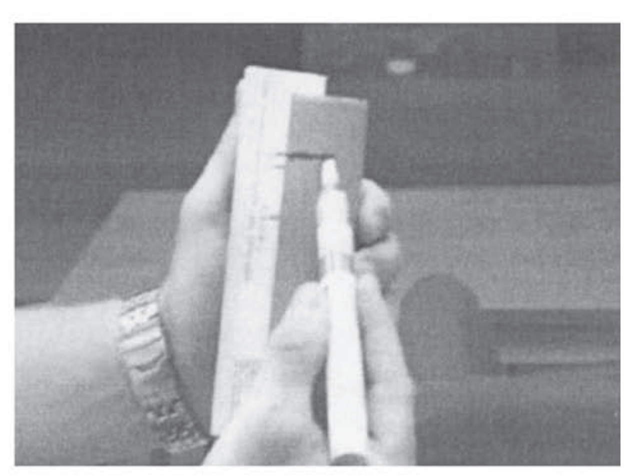
Fusion equipment



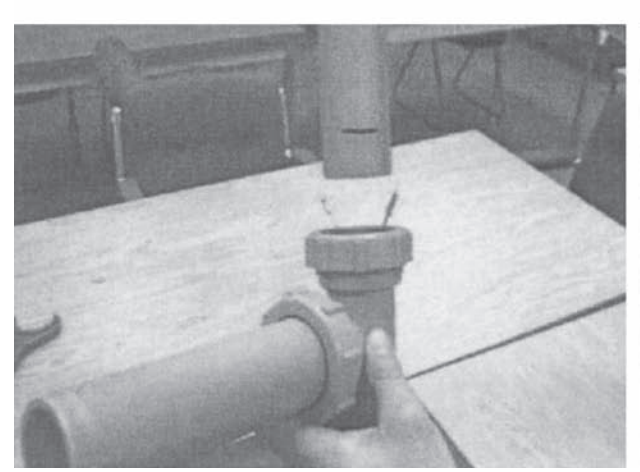
Take nut off fitting, placing fusion coil into fitting socket.



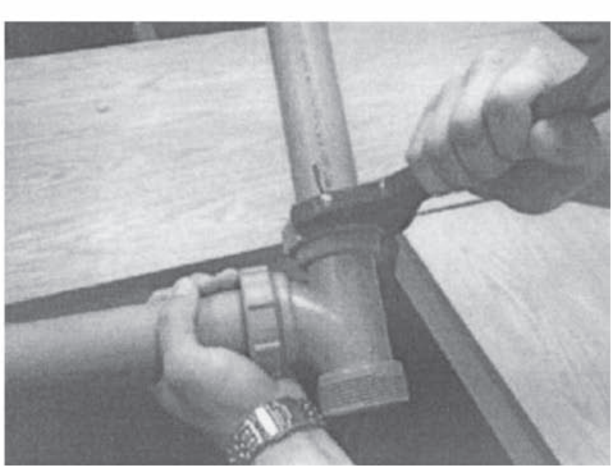
Place nut onto fitting and hand-tighten. Bend leads of coil away from center of fitting to allow room for pipe to be fitted.



Mark the pipe at notch on depth gage that corresponds with size pipe being used.



Place end of pipe into fitting until the mark is flush with top of nut.



Tighten the nuts 1/4 to 1/2 turns using spanner wrench.

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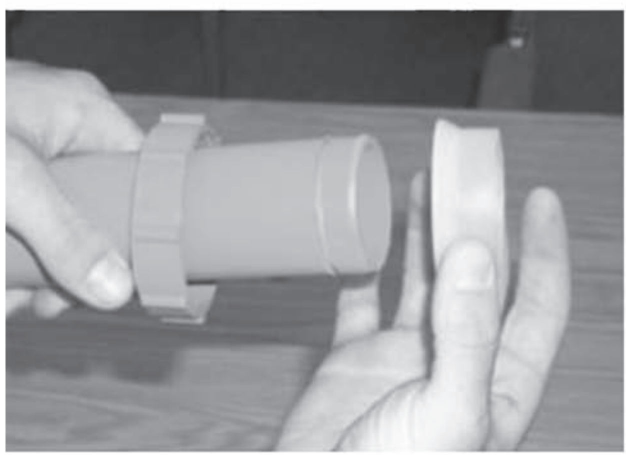
8.9.4 Mechanical Joining of PVC Waste Lines



After cutting and deburring pipe, use pipe tool to groove pipe.

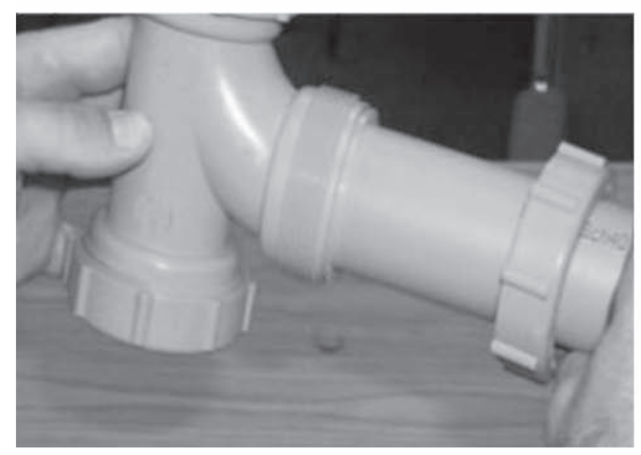


Cut groove in pipe by rotating tool counter-clockwise.

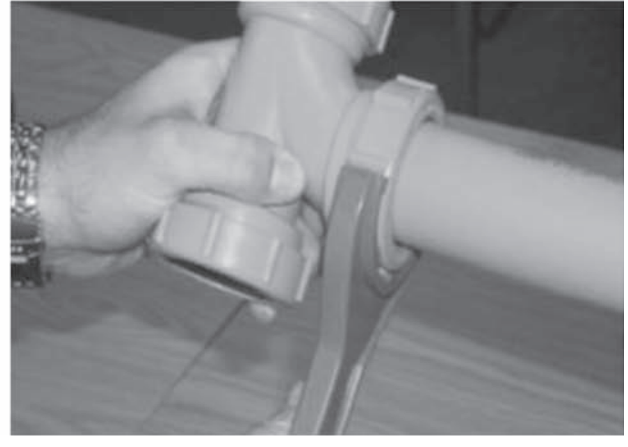




Place compression nut on pipe, then put on seal until it clicks into the groove.



Insert pipe into fitting.



Tighten nut one quarter-turn past hand-tight using a plastic spanner wrench.

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8.9.5 Back Welding of Plastic Pipe

If minute leaks do occur in cemented or fused low-pressure piping systems, back welding may be of use. If the leak is a steady stream, cut out and replace the joint. If the leak does not occur at the joint, cut out the entire section and replace. Before repairing a leak, the joint to be welded must be completely dry. Only skilled plastic welders should repair joint leaks. Adhesive-type repair kits are also available. (Check with cement or other manufacturers.)



Using an appropriate hot-air welding gun and maintaining uniform heat and pressure on the rod, weld a root bead into the prepared joint area.



Apply additional weld beads; number of beads depends on pipe size.



Cut welding rod of similar material at 45 degree angle.



Remove axcess cement residue at pipe joint and make sure the joining is moisture-free.

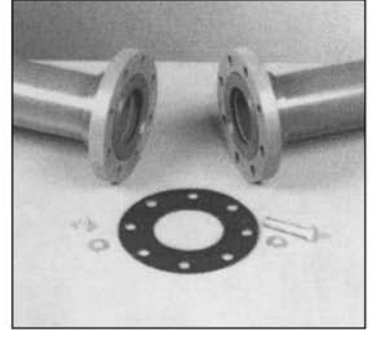
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8.9.6 Flanged Connections for Plastic Pipe

FLANGES AND UNIONS PVC AND CPVC PIPE

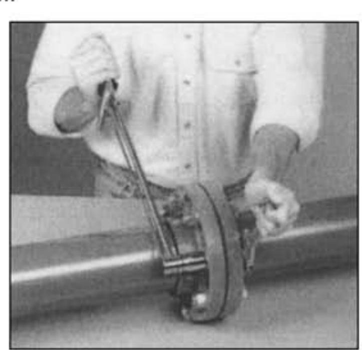
Plastics Technical Manual

For systems where dismantling is required, flanging is a convenient joining method. It is also an easy way to join plastic and metallic systems.



Installation

1. Join the flange to the pipe using the procedures shown in the solvent cementing or threading sections.
2. Use a full faced elastomeric gasket which is resistant to the chemicals being conveyed in the piping system. A gasket 1/8" thick with a Durometer, scale "A", hardness of 55 -80 is normally satisfactory.
3. Align the flanges and gasket by inserting all of the bolts through the mating flange bolt holes. Be sure to use properly sized flat washers under all bolt heads and nuts.
4. Sequentially tighten the bolts corresponding to the patterns shown below.
5. Use a torque wrench to tighten the bolts to the torque values shown below.

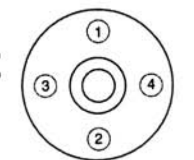


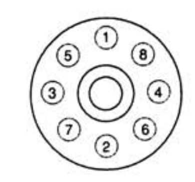
Recommended Torque

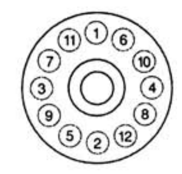
Pipe Size In Inches	No. Bolt Holes	Bolt Diameter	Recommended Torque ft/lbs
1/2	4	1/2	10 - 15
3/4	4	1/2	10 - 15
1	4	1/2	10 - 15
1 1/4	4	1/2	10 - 15
1 1/2	4	1/2	10 - 15
2	4	5/8	20 - 30
2 1/2	4	5/8	20 - 30
3	4	5/8	20 - 30
4	8	5/8	20 - 30
6	8	3/4	33 - 50
8	8	3/4	33 - 50
10	12	7/8	53 - 75
12	12	7/8	53 - 75

Note: Flanges meet the bolt-pattern requirements of ANSI / ASME B 16.5

FLANGE BOLT TIGHTENING SEQUENCE







Pressure Rating of PVC and CPVC Unions and Flanges at Elevated Temperatures

System Operating Temp. Temperature °F (C)			100 (38)	110 (43)	120 (49)	130 (54)	140 (60)	150 (66)	160 (71)	170 (77)	180 (82)	190 (88)	200 (93)	210 (99)
Pressure Rating psi (Mpa)	1/2" - 2"	PVC	235 (1.62)	211 (1.45)	150 (1.03)	75 (.52)	50 (.34)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		CPVC	235 (1.62)	219 (1.51)	170 (1.17)	145 (1.00)	130 (.90)	110 (.76)	90 (.62)	80 (.55)	70 (.48)	60 (.41)	50 (.34)	0 (0)
	2-1/2" - 6"	PVC	150 (1.03)	135 (.93)	110 (.76)	75 (.52)	50 (.34)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		CPVC	150 (1.03)	140 (.97)	130 (.90)	120 (.83)	110 (.75)	100 (.70)	90 (.62)	80 (.55)	70 (.48)	60 (.41)	50 (.34)	0 (0)

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8.9.7 Cold Expansion Fittings to PEX Piping

Cold Expansion Fittings with PEX Reinforced Rings

This type of fitting requires that the PEX piping, with a reinforcing PEX ring placed over the end of the pipe, is expanded before the fitting is inserted into the pipe end. The expanded pipe end is allowed to retract onto the fitting to form the seal—the "memory" of the pipe allows it to tighten over the fitting. An expander tool is required to expand the pipe and the PEX ring together. ASTM F 1960 is applicable to fittings that use a PEX reinforcing ring.

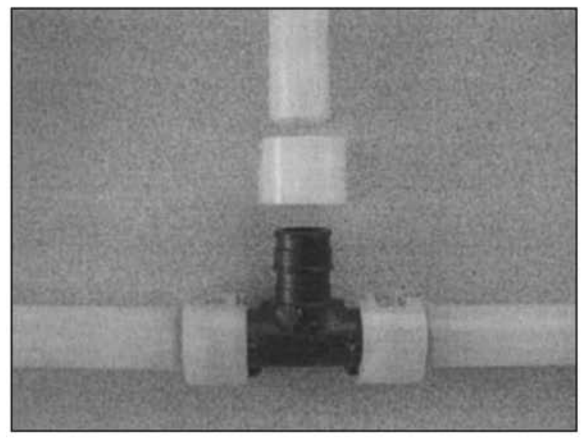


Figure 5.1 – Cold Expansion Polymer Fitting with PEX Reinforced Ring

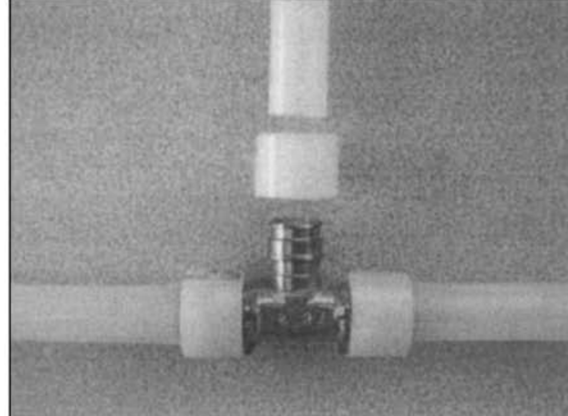


Figure 5.2 – Cold Expansion Metal Fitting with PEX Reinforced Ring

Cold Expansion Fittings with Metal Compression Sleeves

This type of fitting requires that the PEX piping is expanded before it is placed over the oversized fitting. The pipe shrinks down over the fitting insert, then a metal compression sleeve is pulled over the connection, compressing the pipe over the fitting. A tool is required to expand the pipe and to pull the sleeve over the pipe. ASTM F 2080 is applicable to cold expansion fittings that use a metal compression sleeve.

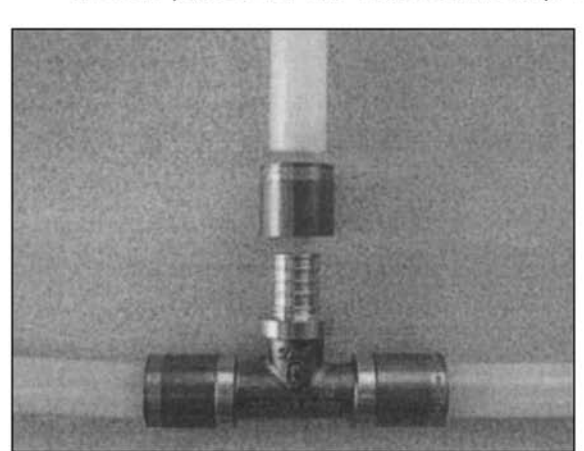


Figure 5.3 – Cold Expansion Fitting with Metal Compression Sleeve

8.9.7 Cold Expansion Fittings to PEX Piping (Continued)

Metal or Plastic Insert Fittings

This type of fitting uses a metal crimp ring that is compressed around the PEX piping to secure it to the fitting. The crimp ring can be copper or stainless steel. Fittings can be made of copper, brass, bronze, or plastic. The fitting will typically have a barbed or ribbed annular end.

The PEX pipe slides over the barbed or ribbed annular section. Prior to making the connection, the metal crimp ring is slid over the PEX piping and away from the end of the pipe. The piping is pushed over the fitting, the crimp ring is slid down over that section and aligned over the fitting ribs, and a tool is used to compress the crimp ring around the assembly.

Copper Crimp Ring

The copper ring is crimped equally around the fitting. The go-no-go gauge ensures a proper crimp. Some manufacturers use o-rings on their metal fittings to make the seal with the pipe. ASTM F 1807 is the applicable standard for metal insert fittings. ASTM F 2159 is the applicable standard for plastic fittings. ASTM 2434 is the applicable standard for metal insert fittings with O-rings.

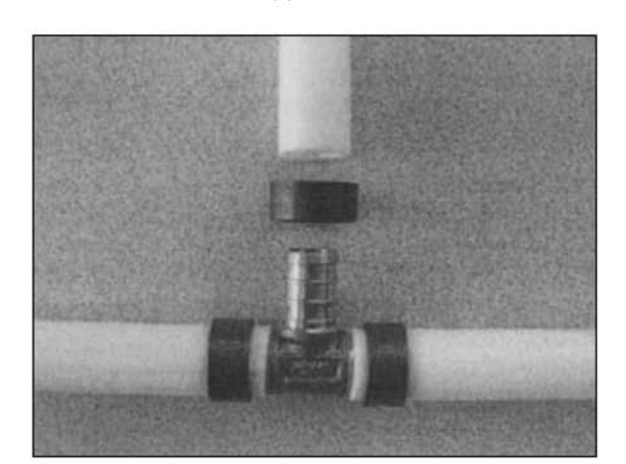


Figure 5.4 – Metal Insert Fitting with Copper Crimp Ring

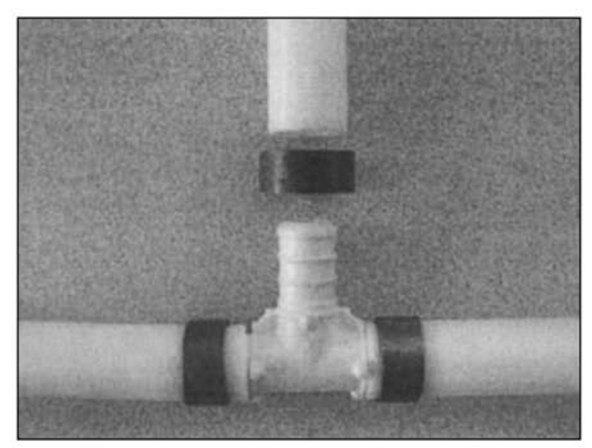


Figure 5.5 – Plastic Insert Fitting with Copper Crimp Ring

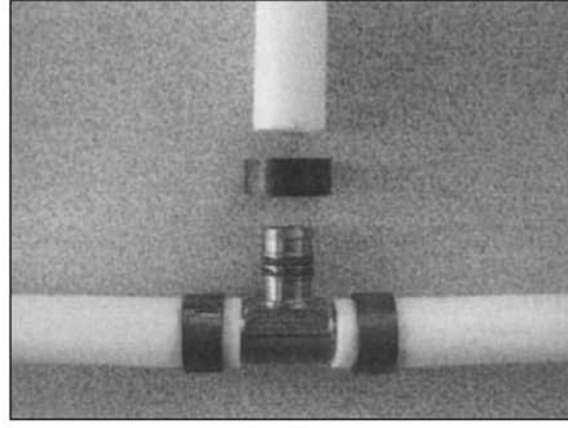


Figure 5.6 – Metal Insert Fitting with O-rings and Copper Crimp Ring

8.10.0 Expansion, Contraction of ABS, PVC, CPVC Pipe

EXPANSION AND CONTRACTION OF ABS, PVC, AND CPVC

ABS, PVC and CPVC pipe, like other piping materials, undergo length changes as a result of temperature variations above and below the installation temperature. They expand and contract 4.5 to 5 times more than steel or iron pipe. The extent of the expansion or contraction is dependent upon the piping material's coefficient of linear expansion, the length of pipe between directional changes, and the temperature differential.

The coefficients of linear expansion (Y) for ABS, PVC, and CPVC (expressed in inches of expansion per 10°F temperature change per 100 feet of pipe) are as follows:

Material	Y (in./10°F/100 ft)
ABS	0.66
PVC	0.36
CPVC	0.408

The amount of expansion or contraction can be calculated using the following formula:

$$e = \frac{Y\,(T_1 - T_2)}{10} \times \frac{Lp}{100}$$

e = Dimensional change due to thermal expansion or contraction (in.)

Y = Expansion coefficient (See table above.) (in./10°F/100 ft)

$(T_1 - T_2)$ = Temperature differential between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential (°F).

Lp = Length of pipe run between changes in direction (ft)

Example: How much expansion (e) can be expected in a 60 foot straight run of 2" diameter PVC pipe installed at 70°F and operating at 120°F?

Solution:

$$e = .360\ \frac{(120 - 70)}{10} \times \frac{60}{100} = .360 \times 5 \times .6 = 1.08 \text{ inches}$$

There are several ways to compensate for expansion and contraction. The most common methods are:

1. Expansion Loops (Fig. 1)
2. Offsets (Fig. 2)
3. Change in direction (Fig. 3)
4. Piston type expansion joints* (Fig. 4)
5. Bellows and/or rubber expansion joints*
6. Flexible Bends*

*The manufacturers of these devices should be contacted to determine the suitability of their products for the specific application.

When installing the expansion loop, no rigid or restraining supports should be placed within the leg lengths of the loop. The loop should be installed as closely as possible to the mid-point between anchors. Piping support guides should restrict lateral movement and direct axial movement into the loop. Lastly, the pipe and fittings should be solvent cemented together, rather than using threaded connections.

Modulus of Elasticity & Working Stress
Table 1

	ABS		PVC		CPVC	
	Modulus of Elasticity (psi)	Working Stress (psi)	Modulus of Elasticity (psi)	Working Stress (psi)	Modulus of Elasticity (psi)	Working Stress (psi)
73° F	250,000	N/A	420,000	2,000	370,000	2,000
90° F	240,000	N/A	380,000	1,500	360,000	1,820
100° F	230,000	N/A	350,000	1,240	350,000	1,640
120° F	215,000	N/A	300,000	800	340,000	1,300
140° F	195,000	N/A	2000,000	400	325,000	1,000
160° F	180,000	N/A	N/A	N/A	310,000	800
180° F	N/A	N/A	N/A	N/A	290,000	500

Modulus Data is Modulus of Elasticiy in Tension per ASTM D 638

Expansion Loop Formula

$$L = \sqrt{\frac{3\,ED\,(\Delta L)}{2S}}$$

Where:

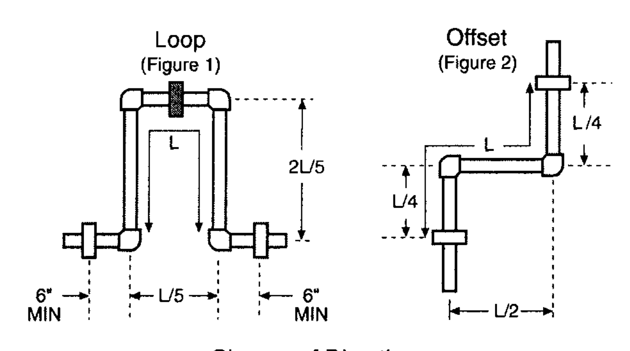
L = Loop length (in.)

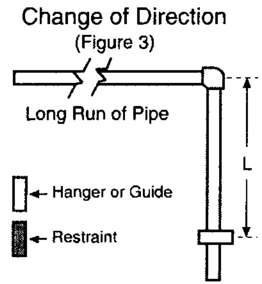
E = Modulus of elasticity at maximum temerature (psi) (Table 1)

S = Working Stress at maximum temperature (psi) (Table 1)

D = Outside diameter of pipe (in.)

ΔL = Change in length due to change in temperature (in.)





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8.10.1 Frictional Loss, Velocity, Flow Rate for PEX Plumbing Tubing

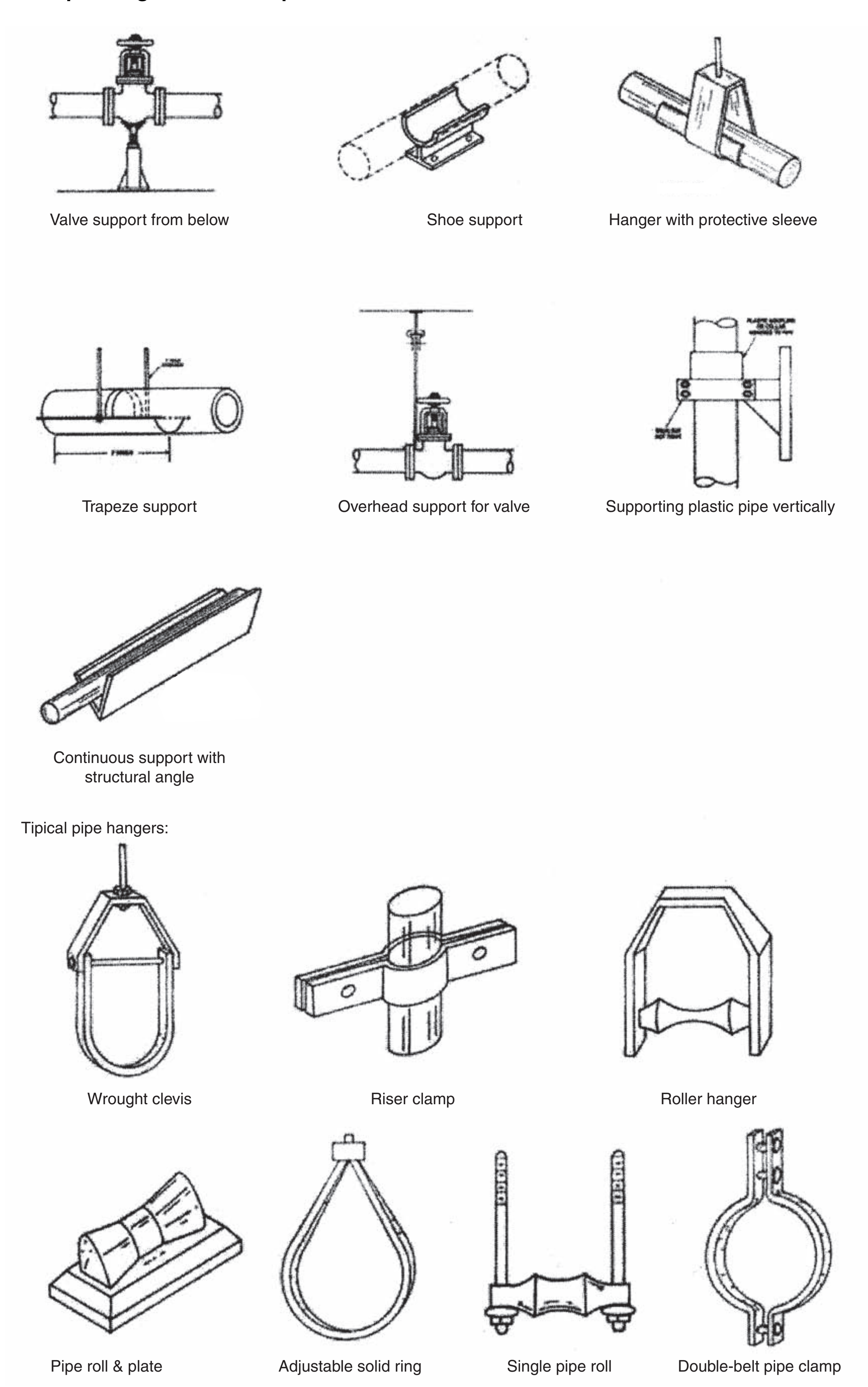
Type of Fitting	Equivalent Length of Tubing (ft.)			
	3/8" size	1/2" size	3/4" size	1" size
Coupling	2.9	2.0	0.6	1.3
Elbow 90°	9.2	9.4	9.4	10.0
Tee-branch	9.4	10.4	8.9	11.0
Tee-run	2.9	2.4	1.9	2.3

Friction Loss and Velocity vs. Flow Rate
PEX Plumbing Tubing (CTS) (ASTM F 876/F 877)

Nominal Size Average ID	3/8" 0.350		1/2" 0.475		3/4" 0.671		1" 0.863	
GPM	F. Loss	Vel	F. Loss	Vel	F. Loss	Vel	F. Loss	Vel
1	7.0	3.33	1.6	1.81	0.3	0.96	0.1	0.55
2	25.4	6.67	5.8	3.62	1.1	1.81	0.3	1.10
3	53.9	10.00	12.2	5.43	2.3	2.72	0.7	1.65
4	91.8	13.34	20.8	7.24	3.9	3.63	1.1	2.19
5			31.4	9.05	5.9	4.54	1.7	2.74
6			44.0	10.86	8.2	5.44	2.4	3.29
7			58.6	12.67	10.9	6.35	3.2	3.84
8					14.0	7.26	4.1	4.39
9					17.4	8.17	5.1	4.94
10					21.1	9.07	6.2	5.48
11					25.2	9.98	7.4	6.03
12					29.6	10.89	8.7	6.58
13					34.3	11.79	10.1	7.13
14					39.4	12.70	11.6	7.68
15							13.2	8.23
16							14.8	8.78

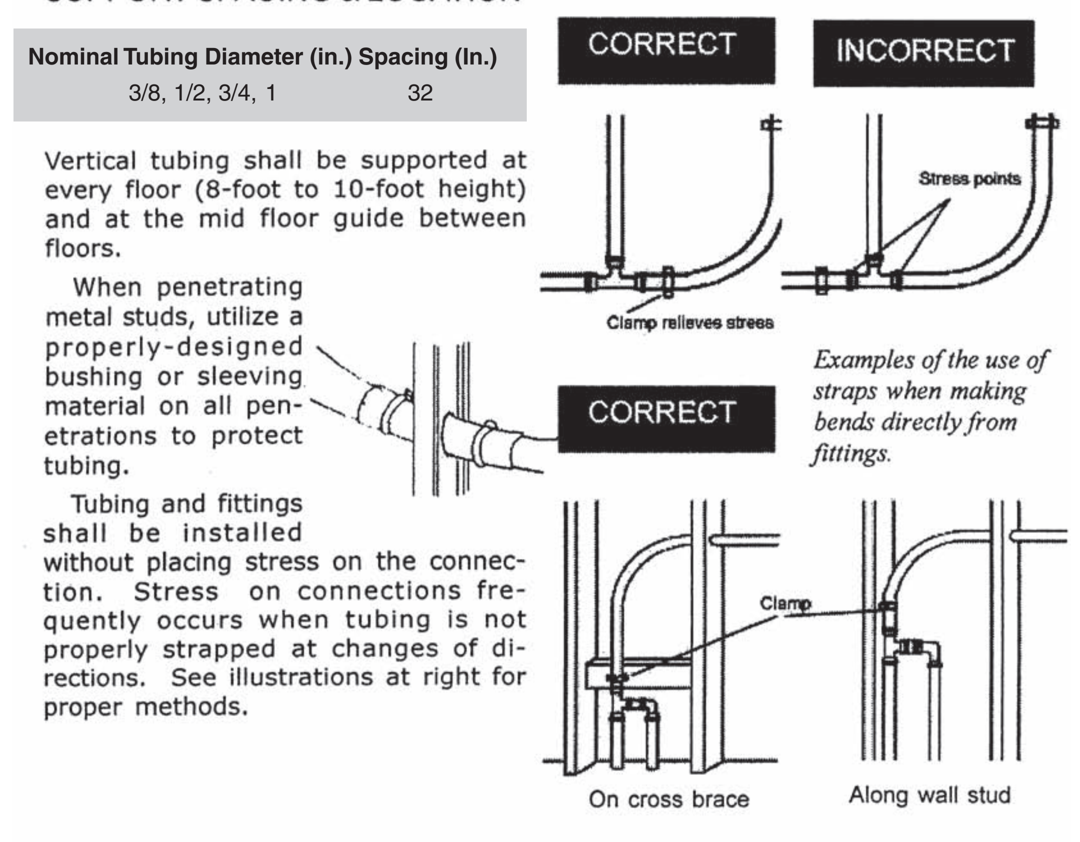
NOTE: Friction Loss based on Hazen-Williams Formula (C = 150)
CTS Tubing manufactured per ASTM F 876/F 877
Friction Loss is expressed as -psi per 100 ft. of tubing
Velocity (VEL) feet per second

8.11.0 Typical Pipe Hangers and Clamps



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8.11.1 Support Spacing to Compensate for Expansion/Contraction



SUPPORT SPACING & LOCATION

Nominal Tubing Diameter (in.)	Spacing (In.)
3/8, 1/2, 3/4, 1	32

Vertical tubing shall be supported at every floor (8-foot to 10-foot height) and at the mid floor guide between floors.

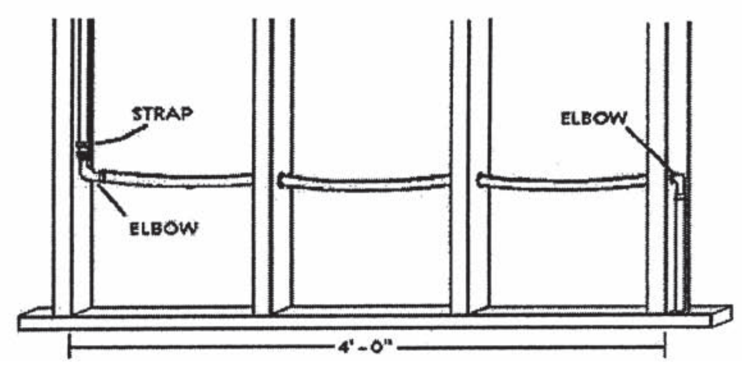
When penetrating metal studs, utilize a properly-designed bushing or sleeving material on all penetrations to protect tubing.

Tubing and fittings shall be installed without placing stress on the connection. Stress on connections frequently occurs when tubing is not properly strapped at changes of directions. See illustrations at right for proper methods.

EXPANSION / CONTRACTION OF TUBING

Do not pull tubing tight during installation. This can cause excessive tensile forces on fittings and connections when tubing cools and contracts. Allow 1/8-inch slack per foot of installed tubing.

Expansion can usually be accommodated by tubing's flexibility for sizes up to and including 1-inch size tubing.



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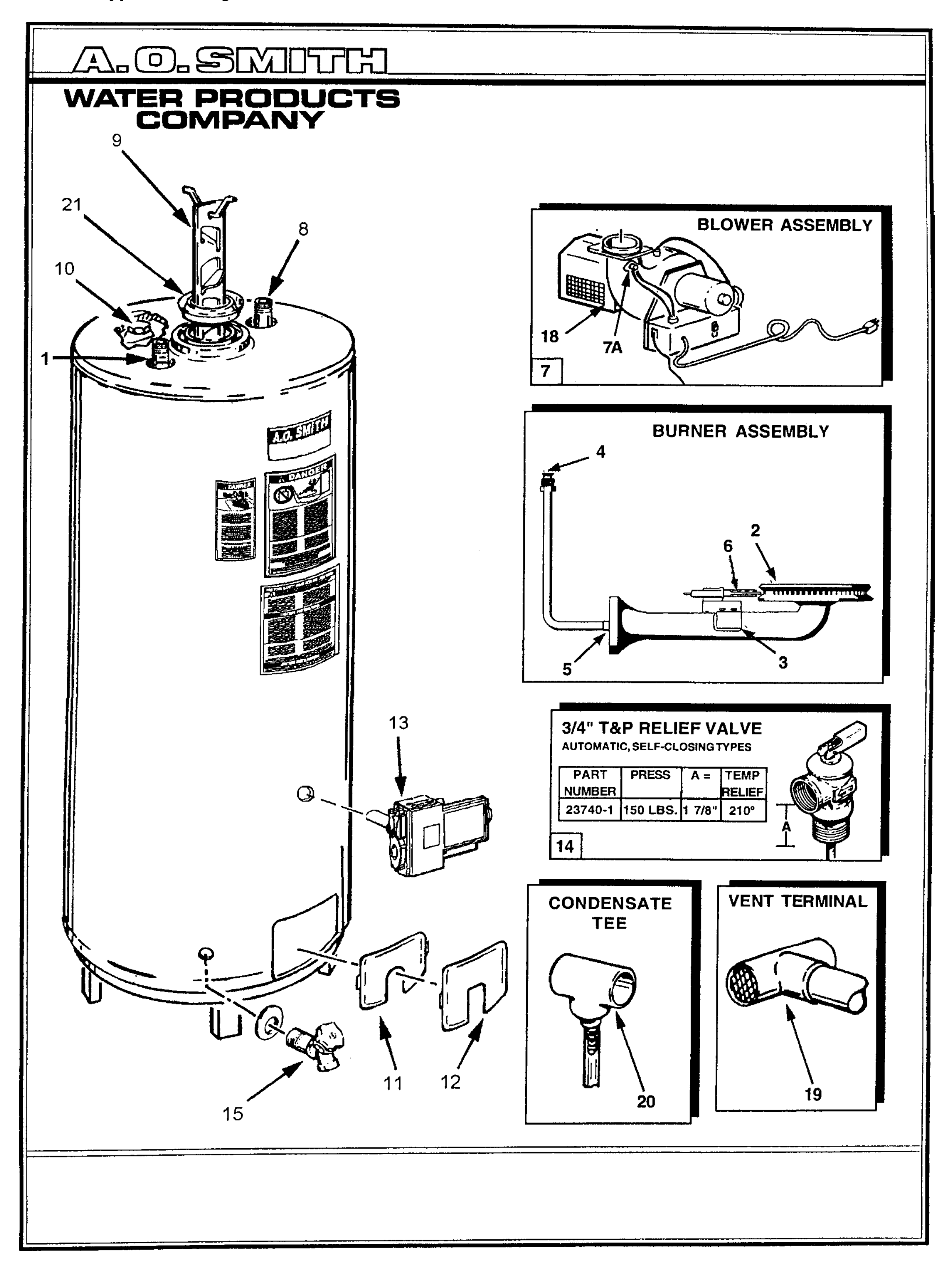
8.12.0 Water Heaters—Various Types

Storage, demand or tankless, heat pumps and indirect water heaters are the most common types of hot water heaters in the United States today, with the storage type at the top of the list.

8.12.1 Storage-Type Hot Water Heaters

Storage-type hot water heaters use gas (natural or propane), oil, and electricity to generate heat which is transferred from a burner or coil to water contained in an insulated tank that ranges in size from 20 to 80 gal or larger. Energy-efficient storage-type heaters range from 0.63 EF (energy factor) to 0.67, the highest available. These heaters, when installed, require outside air and a method to exhaust gases to the exterior.

8.12.1.1 Typical Storage Hot Water Heater and Parts Identification



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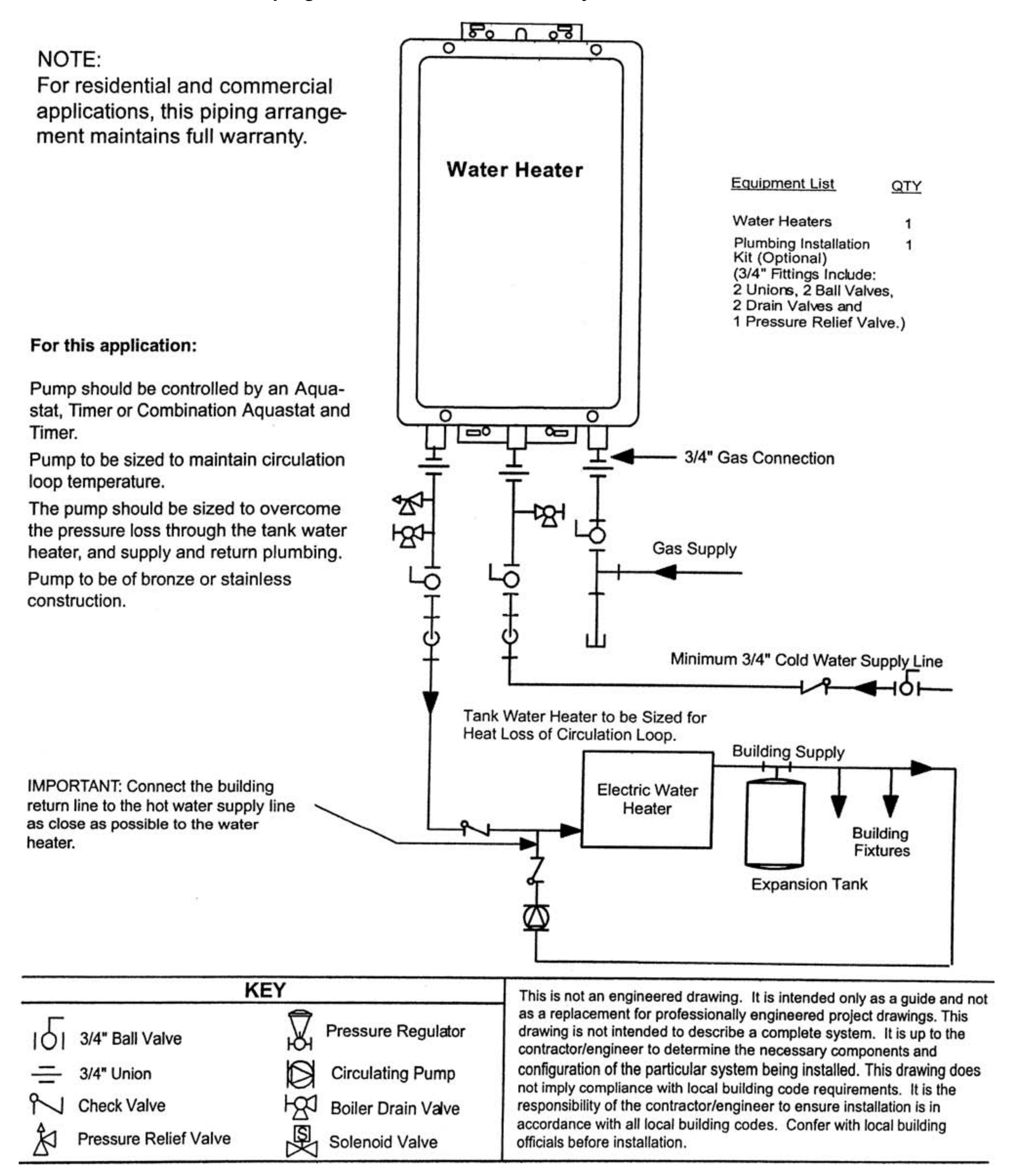
8.12.1.1 Typical Storage Hot Water Heater and Parts Identification (Continued)

Item	Qty.	Description	BTF & FPSE 75 Natural	BTF & FPSE 75 Propane
1	1	Pipe Nipple	43879-1	43879-1
2	1	Cast Iron Burner	41157-5	41157-5
3	1	Ignitor Bracket	194204	194204
4	1	Burner Tube	39114-5	181784-3
5	1	Orifice	29336-21	181510-39
6	1	Igniter/Flame Sensor	194057	194057
7	1	Blower	194220	194220
7A	1	Termal Switch	21230	21230
7B	1	Presssure Switch	21235	21235
8	1	Inlet Tube	194054	194054
9	1	Flue Baffle Assembly	182193	182193
10	1	Anode Rod	43817-38	43817-38
11	1	Inner Door	39923	39923
12	1	Outer Door	39112-1	39112-1
13	1	Thermostat, SmartValve™	183082-4	183082-5
*14	1	T & P Relief Valve	23740-1	23740-1
*15	1	Drain Valve	26273-7	26273-7
16	1	Wire Harness	183089	183089
17	1	Manual	194373	194373
18	1	Fan Housing	182165	182165
19	1	Vent Terminal	181617	181617
20	1	Condensate Tee	181861	181861
21	1	Flue Restrictor	35405	35405

* Not Illustrated

By permission, A.O. Smith.

8.12.1.2 Recommended Piping for Hot Water Circulation Systems



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8.12.1.3 Optional Piping System for Hot Water Circulation

NOTE:
For residential and commercial applications, this piping arrangement reduces the warranty to the following:

3 years on heat exchanger

3 year on parts

Full warranty will be maintained if an on-demand recirculation system in incorporated. Refer to the Limited Warranty.

For this application:

Pump should be controlled by an Aquastat, Timer or Combination Aquastat and Timer.

Pump to be sized to maintain circulation loop temperature.

A minimum of 3 GPM flow is recommended for the circulation system.

The pump should be sized to overcome the pressure loss through the water heate r, supply and return plumbing.

Pump to be of bronze or stainless construc - tion.

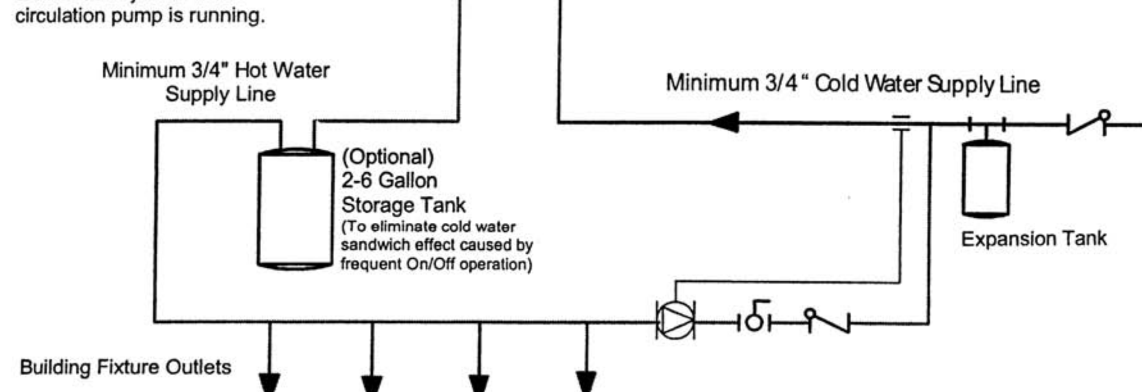
Note: Water heater outlet temperature cannot be adjusted when circulation pump is running.

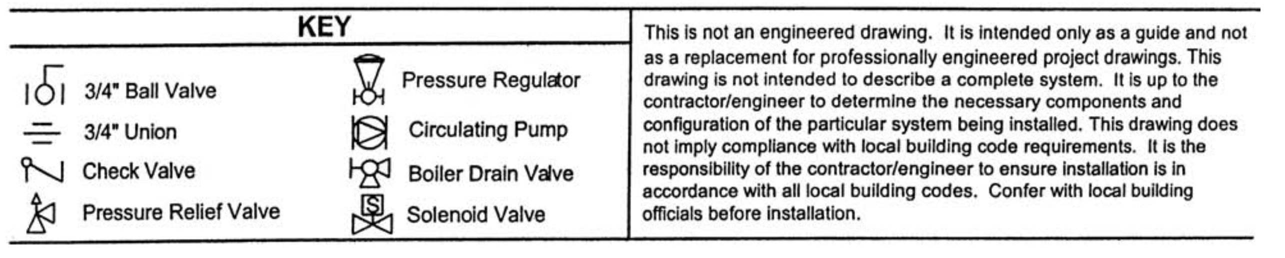
Water Heater

Equipment List	QTY
Water Heaters	1
Plumbing Installation Kit (Optional) (3/4" Fittings Include: 2 Unions, 2 Ball Valves, 2 Drain Valves and 1 Pressure Relief Valve.)	1

3/4" Gas Connection

Gas Supply





By permission, A.O. Smith.

8.12.1.4 Mixing Valve Installation on Storage-Type Hot Water Heater

VENTING

⚠ WARNING
THE INSTRUCTIONS IN THIS SECTION ON VENTING MUST BE FOLLOWED TO AVOID CHOKED COMBUSTION OR RECIRCULATION OF FLUE GASES. SUCH CONDITIONS CAUSE SOOTING OR RISKS OF FIRE AND ASPHYXIATION.

Heater must be protected from freezing downdrafts.

Remove all soot or other obstructions from the chimney that will retard a free draft.

Type B venting is recommended with these heaters.

This water heater must be vented in compliance with all local codes, the current edition of the National Fuel Gas Code, ANSI Z223.1/NFPA 54, and with the Category I Venting Tables.

In Canada, venting shall conform to the requirements of the current edition of the CAN/CSA B149.1-00 installation code.

If any part of the vent system are exposed to ambient temperatures below 35 degrees F (2 degrees C) it must be insulated to prevent condensation.

- Do not connect the heater to a common vent or chimney with solid fuel burning equipment. This practice is prohibited by many local building codes as is the practice of venting gas fired equipment to the duct work of ventilation systems.
- Where a separate vent connection is not available and the vent pipe from the heater must be connected to a common vent with an oil burning furnace, the vent pipe should enter the smaller common vent or chimney at a point above the large vent pipe.

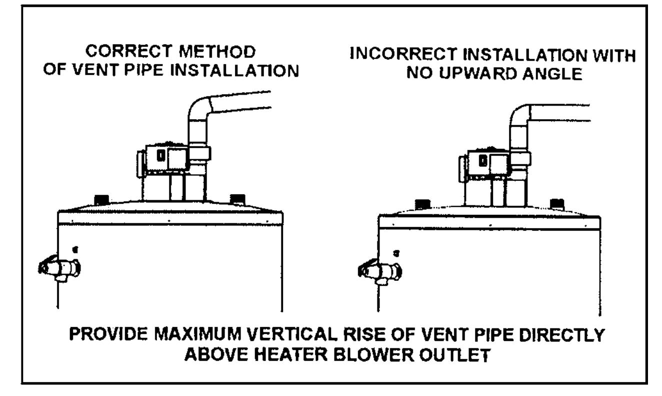


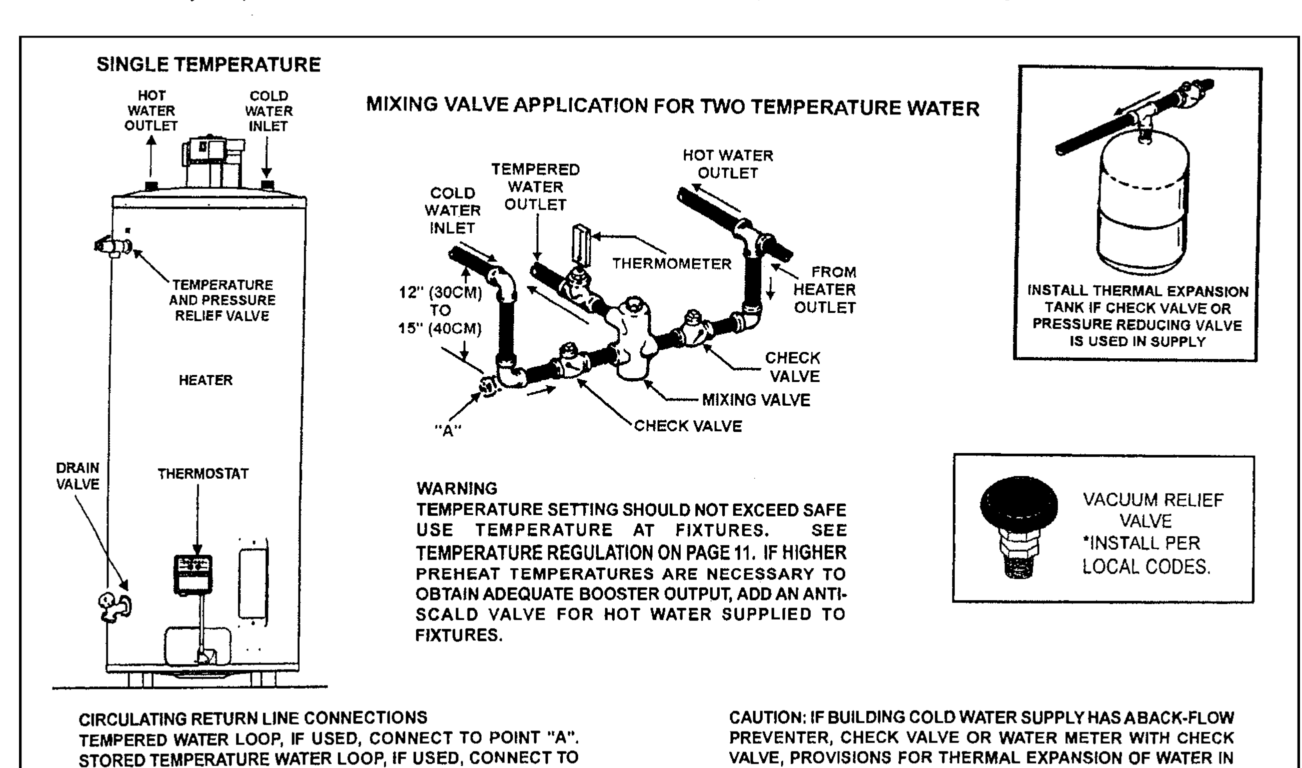
FIGURE 2.

VENT CONNECTION

Vent connections must be made to an adequate stack or chimney. Size and install proper size vent pipe. Do not reduce pipe size to less than that of the blower outlet.

Horizontal runs of vent pipe must have a minimum upward slope toward the chimney of 1/4 inch per foot (2cm per meter). Dampers or other obstructions must not be installed in between the heater and the blower. Be sure that the vent pipe does not extend beyond the inside wall of the chimney.

Where a continuous or intermittent back draft is found to exist, the cause must be determined and corrected. A special vent cap may be required. If the back draft cannot be corrected by the normal methods or if a suitable draft cannot be obtained, a blower type flue gas exhauster must be employed to assure proper venting and correct combustion.



By permission, A.O. Smith.

8.13.0 Demand, or Tankless, Heaters

These heat water only when there is a demand and theoretically never run out of hot water.

8.14.0 Heat Pump Hot Water Heaters

This heater uses significantly less energy than a conventional resistance-type heater since the heat source is outside air or air in the room where the unit is installed. Like the more familiar heat pump for heating and cooling, the hot water heater operates on the principle of moving heat from one place to another rather than generating the heat directly. Heat pump heaters are available with built-in water tanks or as add-ons to existing hot water storage tanks.

8.15.0 Solar Water Heaters

Three types of solar collectors are used for residential applications. Larger commercial applications require an expanded collector array and larger insulated storage tanks, but the concept of solar collectors is basically the same.

8.15.1 Flat Plate Collectors

Glazed flat plate collectors are insulated, waterproof boxes containing a dark absorber plate under a glass or polymer cover.

8.15.2 Integral Collector-Storage (ICS) Systems

Referred to as ICS or batch systems, these feature one or more black tanks or tubes in an insulated glass or plastic covered box. As cold water passes through the solar collector, this preheats the water which continues to a conventional backup water heater. This system can be used in only those climates where outdoor, water-filled pipes will not freeze.

8.15.3 Evacuated-Tube Solar Collectors

These collectors contain parallel rows of transparent glass tubes, each of which contains a glass outer tube and a metal absorber tube attached to a fin. The fin's coating absorbs solar energy and inhibits radiative heat loss. These types of collectors are used in many commercial applications.

8.16.0 Definitions Used in the Plumbing Trade

AEROBIC—Living with air.

ABSORPTION—Applies to immersion in a fluid for a definite period of time. Usually expressed as a percent of the weight of the dry pipe.

ANAEROBIC—Living without air.

ANCHOR—Usually a piece of metal used to fasten or secure pipes to the building or structure.

AREA OF CIRCLE—The square of the radius multiplied by π(3.1416). Area = π^2 or (rxrx3.1416).

BACKFILL—Portion of the trench excavation that is replaced after the sewer line has been laid. The material above the pipe up to the original earth line.

BACKFLOW—The flow of water or other liquids, mixtures, or substances into the distribution pipe of a potable supply of water from any source other than that intended.

BACKFLOW PREVENTER—A device or assembly designed to prevent backflow into the potable water system.

BACK-SIPHONAGE—A term applied to the flow of used water, wastes, and/or contamination into the potable water supply piping due to vacuums in the distribution system, building service, water main or parts thereof.

By permission, Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.16.0 Definitions Used in the Plumbing Trade (Continued)

BASE—The lowest portion or lowest point of a stack of vertical pipe.

BRANCH—Any part of the piping system other than a main riser, or stack.

CAST IRON SOIL PIPE—The preferred material for drain, waste, vent, and sewer systems.

CAULKING—A method of sealing against water or gas by means of pliable substances, such as lead and oakum.

CI No-Hub® — A registered trademark of the Cast Iron Soil Pipe Institute.

CIRCUMFERENCE OF CIRCLE—The diameter of the circle multiplied by π. Circumference = πD.

CLARIFIED SEWAGE—A term used for sewage from which suspended matter has been removed.

CODE—An ordinance, rule, or regulation that a city or governing body may adopt to control the plumbing work within its jurisdiction.

COLIFORM BACTERIA—Organisms in the *coili aerogenes* group, as set forth in the American Water Works Association and the American Public Health Association literature.

COMPRESSION—Stress that resists the tendency of two forces acting toward each other.

CONDUCTOR—That part of the vertical piping which carries the water from the roof to the storm drain, which starts either six inches above grade if outside the building, or at the roof sump or gutter if inside the building.

CROSS CONNECTION—(or inter-connection) Any physical connection between a city water supply and any waste pipe, soil pipe, sewer, drain, or any private or uncertified water supply. Any potable water supply outlet that is submerged or can be submerged in wastewater and/or any other source of contamination.

CRUDE OR RAW SEWAGE—Untreated sewage.

DEAD END—A branch leading from any soil, waste, or vent pipe, building drain, or building sewer, which is terminated at a distance of two feet or more by means of a cap, plug, or other fitting not used for admitting water or air to the pipe, except branches serving as cleanout extensions.

DEVELOPED LENGTHS—Length measured along the center line of the pipe and fittings.

DIAMETER—A straight line that passes through the center of a circle and divides it in half.

DIGESTER/DIGESTION—Portion of the sewage treatment process when biochemical decomposition of organic matter takes place, resulting in the formation of simple organic and mineral substances.

DOMESTIC SEWAGE—Sewage originating principally from dwellings, business buildings, and institutions, and usually not containing storm water. In some localities it may include industrial wastes and rain water from combination sewers.

DRAIN—Any pipe that carries wastewater or water-borne wastes in a building drainage system.

DRAIN, BUILDING OR HOUSE—Part of the lowest horizontal piping of a building drainage system that receives and conveys the discharge from soil, waste, and drainage pipes, other than storm drains, from within the walls or footings of any building to the building sewer.

DRAINS, COMBINED—Portion of the drainage system within a building that carries storm water and sanitary sewage.

DRAINS, STORM—Piping and its branches that convey subsoil and/or surface water from areas, courts, roofs, or yards to the building or storm sewer.

DRAINS, SUBSOIL—Part of the drainage system that conveys the subsoil, ground, or seepage water from the footings of walls or from under buildings to the building drain, storm water drain, or building sewer.

DRY-WEATHER FLOW—Sewage collected during the dry weather that contains little or no ground water and no storm water.

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8.16.0 Definitions Used in the Plumbing Trade (Continued)

DUCTILITY—The property of elongation above the elastic limit but short of the tensile strength.

EFFLUENT—Sewage, treated or partially treated, flowing from sewage treatment equipment.

ELASTIC LIMIT—The greatest stress a material can withstand without permanent deformation after release of stress.

EROSION—The gradual destruction of metal or other materials by the abrasive action of liquids, gases, solids, or mixtures of these materials.

EXISTING WORK—Portion of a plumbing system that has been installed prior to current or contemplated addition, alteration or correction.

FIXTURES, BATTERY OF—Any group of two or more similar adjacent fixtures that discharge into a common horizontal waste or soil branch.

FIXTURES, COMBINATION—Any integral unit, such as a kitchen sink or laundry unit.

FIXTURES, PLUMBING—Installed receptacles, devices, or appliances that are supplied with water, or which receive liquids and/or discharge liquids, or liquid-borne wastes, either directly or indirectly into a drainage system.

FIXTURE UNIT—Amount of fixture discharge equivalent to 7½ gallons or more; one cubic foot of water per minute.

FLOOD LEVEL RIM—The top edge of the receptacle from which water overflows.

FLUSH VALVE—A device located at the bottom of the tank for flushing water closets and similar fixtures.

FLUSHOMETER VALVE—A device that discharges a predetermined quantity of water to a fixture for flushing purposes; powered by direct water pressure.

FOOTING—The part of a foundation wall resting on the bearing soil, rock, or piling that transmits the superimposed load to the bearing material.

FRESH SEWAGE—Sewage of recent origin still containing free dissolved oxygen.

INVERT—A line that runs lengthwise along the base of the channel at the lowest point on its wetted perimeter, its slope established when the sewer or drain is installed.

LATERAL SEWER—A sewer that does not receive sewage from any other common sewer except house connections.

LEACHING WELL OR CESSPOOL—Any pit or receptacle with porous walls that permits the contents to seep into the ground

LEADER—The piping from the roof that carries rainwater.

MAIN SEWER—The main stem or principal artery of the sewage system to which branches may be connected (also called the trunk sewer).

MASTER PLUMBER—A plumber licensed to install and assume responsibility for contractual agreements pertaining to plumbing and to secure any required permits. The journeyman plumber is licensed to install plumbing under the supervision of a master plumber.

NO-HUB—Classification of cast iron soil pipe joined using no-hub couplings. Also referred to as hubless and CI No-Hub®

NO-HUB Couplings—Used for joining hubless pipe and fittings.

OFFSET—In a line of piping, a combination of pipe, pipes, and/or fittings that join two approximately parallel sections of a line of pipe.

OUTFALL SEWERS— Sewers that receive sewage from the collection system and carry it to the point of final discharge or treatment; usually the largest sewer of a system.

OXIDIZED SEWAGE—Sewage in which the organic matter has been combined with oxygen and has become stable.

By permission, Cast Iron Soil Pipe Institute, Chattanooga, TN.

8.16.0 Definitions Used in the Plumbing Trade (Continued)

PIPE, HORIZONTAL—Any pipe installed in a horizontal position or that makes an angle of less than 45° from the horizontal.

PIPE, INDIRECT WASTE—Pipe that does not connect directly with the drainage system but conveys liquid wastes into a plumbing fixture or receptacle that is directly connected to the drainage system.

PIPE, LOCAL VENTILATING—A pipe on the fixture side of the trap through which pipe vapors or foul air can be removed from a room fixture.

PIPE, SOIL—Any pipe which conveys to the building drain or building sewer the discharge of one or more water closets and/or the discharge of any other fixture receiving fecal matter, with or without the discharge from other fixtures.

PIPE, SPECIAL WASTE—Drain pipe that receives one or more wastes that require treatment before entry into the normal plumbing system; the special waste pipe terminates at the treatment device on the premises.

PIPE, VERTICAL—Any pipe installed in a vertical position or that makes an angle of not more than 45° from the vertical.

PIPE, WASTE—A pipe that conveys only liquid or liquid-borne waste, free of fecal matter.

PIPE, WATER RISER—A water supply pipe that extends vertically one full story or more to convey water to branches or fixtures.

PIPE, WATER DISTRIBUTION—Pipes that convey water from the service pipe to its points of usage.

PIPES, WATER SERVICE—That portion of the water piping which supplies one or more structures or premises and that extends from the main to the meter or, if no meter is provided, to the first stop cock or valve inside the premises.

PITCH—The amount of slope given to horizontal piping, expressed in inches or vertically projected drop per foot of horizontal pipe.

PLUMBING—The practice, materials, and fixtures used in the installation, maintenance, extension, and alteration of all piping, fixtures, appliances, and appurtenances in connection with any of the following: Sanitary drainage or storm drainage facilities; venting system and public or private water-supply systems; also the practice and materials used in the installation, maintenance, extension, or alteration of water-supply systems and/or the storm water, liquid waste, or sewage system of any premises to their connection with any point of public disposal or other acceptable termina.

PLUMBING INSPECTOR—Any person who, under the supervision of the Authority Having Jurisdiction, is authorized to inspect plumbing and drainage as defined in the code for the municipality, and complying with the laws of licensing and/or registration of the State, City, or County.

PRECIPITATION—The total measurable supply of water received directly from clouds as snow, rain, hail, and sleet. It is usually expressed in inches per day, month, or year.

PRIVATE USE— A term which applies to a toilet room or bathroom intended specifically for the use of an individual or family and such visitors as they may permit to use such toilet or bathroom.

PUBLIC USE—A term that applies to toilet rooms and bathrooms used by employees, occupants, visitors, or patrons in or about any premises.

PUTREFACTION—Biological decomposition of organic matter resulting in foul-smelling products. It usually takes place where there is a deficiency of oxygen.

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8.16.0 Definitions Used in the Plumbing Trade (Continued)

REVENT (individual vent)—Part of a vent pipe line that connects directly with any individual waste pipe or group of wastes, underneath or behind the fixture, and extends to the main or branch vent pipe.

ROUGHING IN—A term referring to the installation of all parts of the plumbing system that should be completed before the installation of plumbing fixtures. Includes drainage, water supply, vent piping, and necessary fixture connections.

SANITARY SEWER—The conduit of pipe carrying sanitary sewage, storm water, and infiltration of ground water.

SEPTIC SEWAGE—Sanitary sewage undergoing putrefaction.

SEPTIC TANK—A receptacle that receives the discharge of a drainage system or part thereof, and is designed and so constructed as to separate solids from liquids to discharge into the soil through a system of open-joint or perforated piping, or into a disposal pit.

SEWAGE—Any liquid waste containing animal, vegetable, or chemical wastes in suspension or solution.

SEWER, BUILDING—Also called house sewer. That part of the horizontal piping of a drainage system extending from the building drain, storm drain, and/or subsoil drain to its connection into the point of disposal and carrying the drainage of a building or part thereof.

SEWER, BUILDING STORM—The extension from the building storm drain to the point of disposal (also called house storm sewer).

SEWER, PRIVATE—A sewer located on private property that conveys the drainage of one or more buildings to a public sewer or to a privately owned sewage disposal system.

SEWER, STORM—A sewer used to convey rainwater, surface water, condensate, cooling water, or similar water wastes, exclusive of sewage and industrial wastes.

SLICK—The thin, oily film that gives the characteristic appearance to the surface of water into which sewage or oily water is discharged.

SLUDGE—The accumulated suspended solids of sewage deposited in tanks, beds, or basins mixed with sufficient water to form a semiliquid mass.

STACK—The vertical main of a system of soil, waste, or vent piping.

STACK VENT—The extension of a soil or waste stack above the highest horizontal drain connected to the stack.

STALE SEWAGE—Sewage that contains little or no oxygen but is free from putrefaction.

STRAIN—Change of shape or size produced by stress.

STRESS—External forces resisted by reactions within.

SUB-MAIN SEWER—A sewer into which the sewage from two or more lateral sewers is discharged (also called branch sewer).

SUBSOIL DRAIN—A drain that receives the discharge from drains or other wastes located below the normal grade of the gravity system, which must be emptied by mechanical means.

SUMP—A tank or pit that receives the discharge from drains or other wastes, located below the normal grade of the gravity system, which must be emptied by mechanical means.

TENSION—That stress that resists the tendency of two forces acting opposite from each other to pull apart two adjoining planes of a body.

TRAP—A fitting or device so designed and constructed as to provide, when properly vented, a liquid seal that will prevent the back passage of air or sewer gas without materially affecting the flow of sewage or wastewater through it.

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8.16.0 Definitions Used in the Plumbing Trade (Continued)

TRAP SEAL—The vertical distance between the crown weir and the top of the dip of the trap.

TURBULENCE—Any deviation from parallel flow.

UNDERGROUND PIPING—Piping in contact with the earth below grade. Pipe in a tunnel or in a watertight trench is not included within the scope of this term.

VACUUM—Any pressure less than that exerted by the atmosphere (also called negative pressure).

VELOCITY—Time rate of motion in a given direction.

VENT, CIRCUIT—A branch vent that serves two or more traps and extends from in front of the last fixture connection of a horizontal branch to the vent stack.

VENT, COMMON—Also called dual vent, vent connecting at the junction of two fixture drains and serving as a vent for both fixtures.

VENT, CONTINUOUS—A vent that is a continuation of the drain to which it connects. A continuous vent is further defined by the angle which the drain and vent make with the horizontal at the point of connection; for example, vertical continuous waste-and-vent, 45° continuous waste-and-vent, and flat (small angle) continuous waste-and-vent.

VENT STACK—A vertical vent pipe installed primarily to provide circulation of air to that part of a venting system to which circuit vents are connected. Branch vents, revents, or individual vents may be led to and connected with a vent stack. The foot of the vent stack may be connected either into a horizontal drainage branch or into a soil or waste stack.

VENT SYSTEM—Pipes installed to provide airflow to or from a drainage system or to provide air circulation within such system to protect trap seals from siphonage and back pressure.

VENT, WET—A vent that receives the discharge of wastes other than from water closets.

VENTING, STACK—A method of venting a fixture through the soil and waste stack.

VENTS, INDIVIDUAL—Separate vents for each fixture.

WASTE—The discharge from any fixture, appliance, or appurtenance in connection with the plumbing system that does not contain fecal matter. For example, the liquid from a lavatory, a tub, a sink, or a drinking fountain.

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8.17.0 Recommended Symbols for Plumbing Fixtures

Symbols for Fixtures[1]

CORNER BATH

RECESSED BATH

ROLL RIM BATH

SB

SITZ BATH

FB

FOOT BATH

B

BIDET

SHOWER STALL

SHOWER HEAD

PLAN ELEV.

PLAN

OVERHEAD GANG SHOWER

ELEV.

P.L.

PEDESTAL LAVATORY

W.L.

WALL LAVATORY

LAV.

CORNER LAVATORY

ML

MANICURE LAVATORY

DENTAL LAV.

DENTAL LAVATORY

S

PLAIN KITCHEN SINK

KITCHEN SINK, R&L DRAIN BOARD

KITCHEN SINK, LH DRAIN BOARD

COMBINATION SINK AND DISH WATER

S & T

COMBINATION SINK AND LAUNDRY TRAY

SS

SERVICE SINK

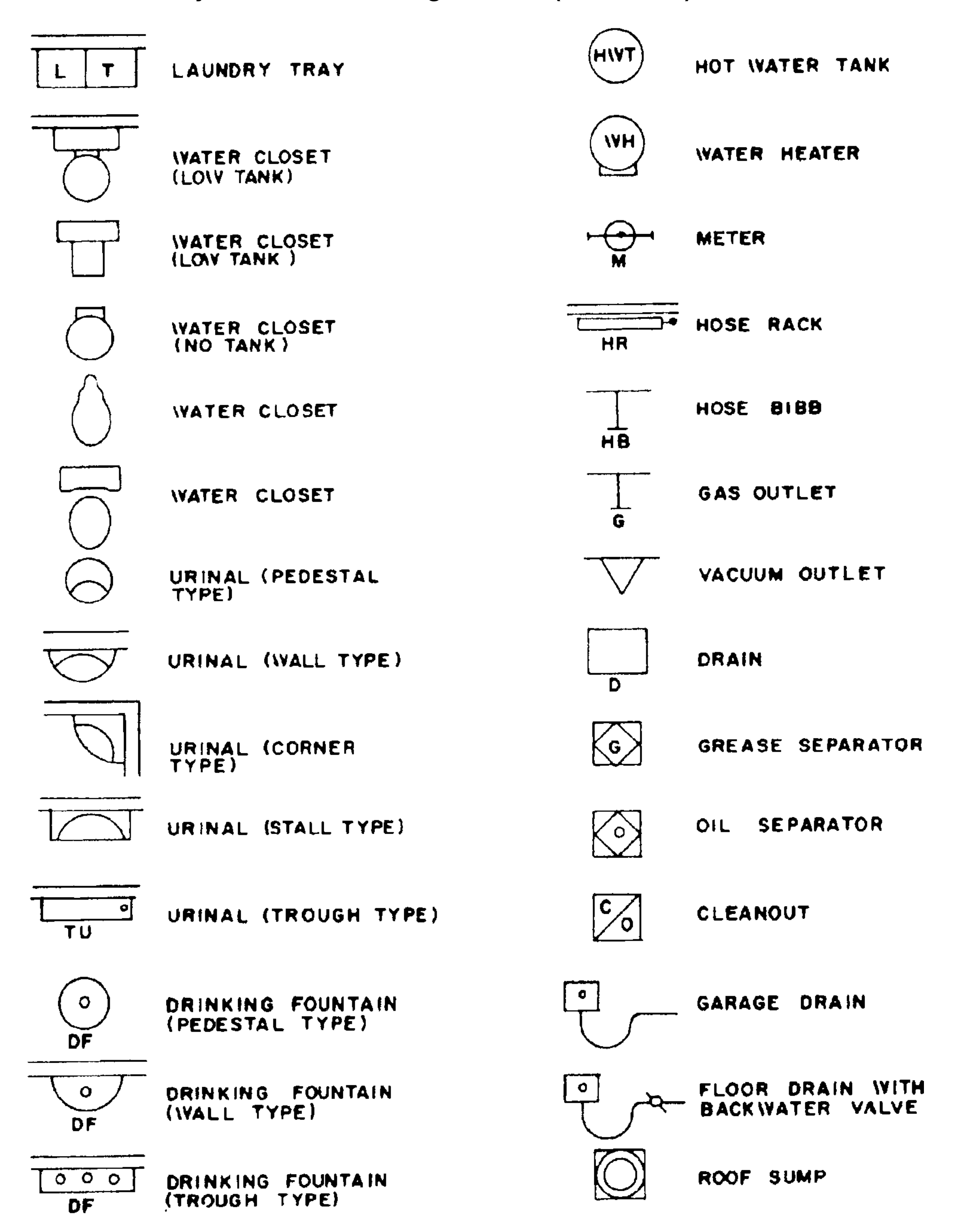
WASH SINK, WALL TYPE.

WASH SINK

[1] Symbols adopted by the American National Standards Association (ANSI)

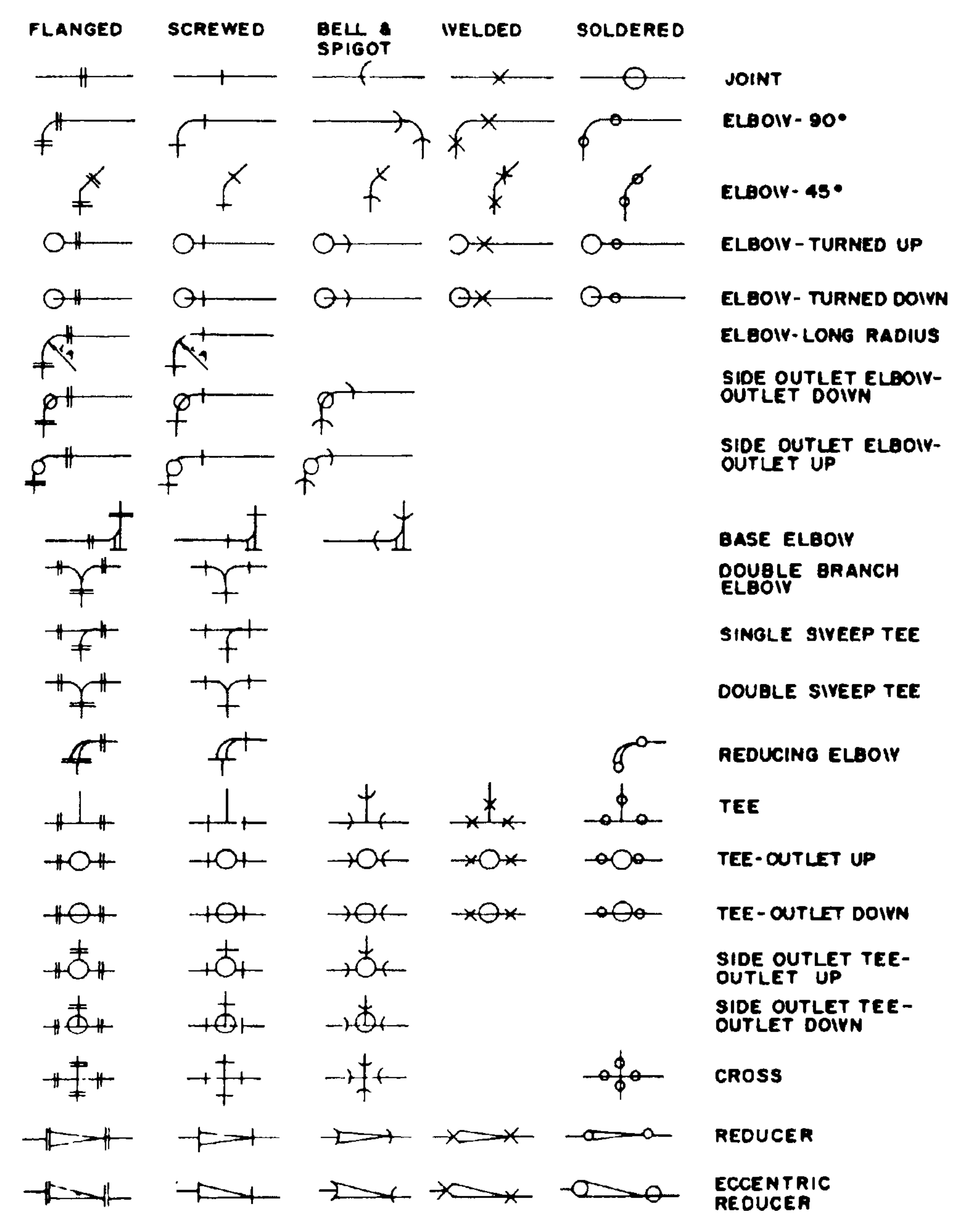
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8.17.0 Recommended Symbols for Plumbing Fixtures (Continued)



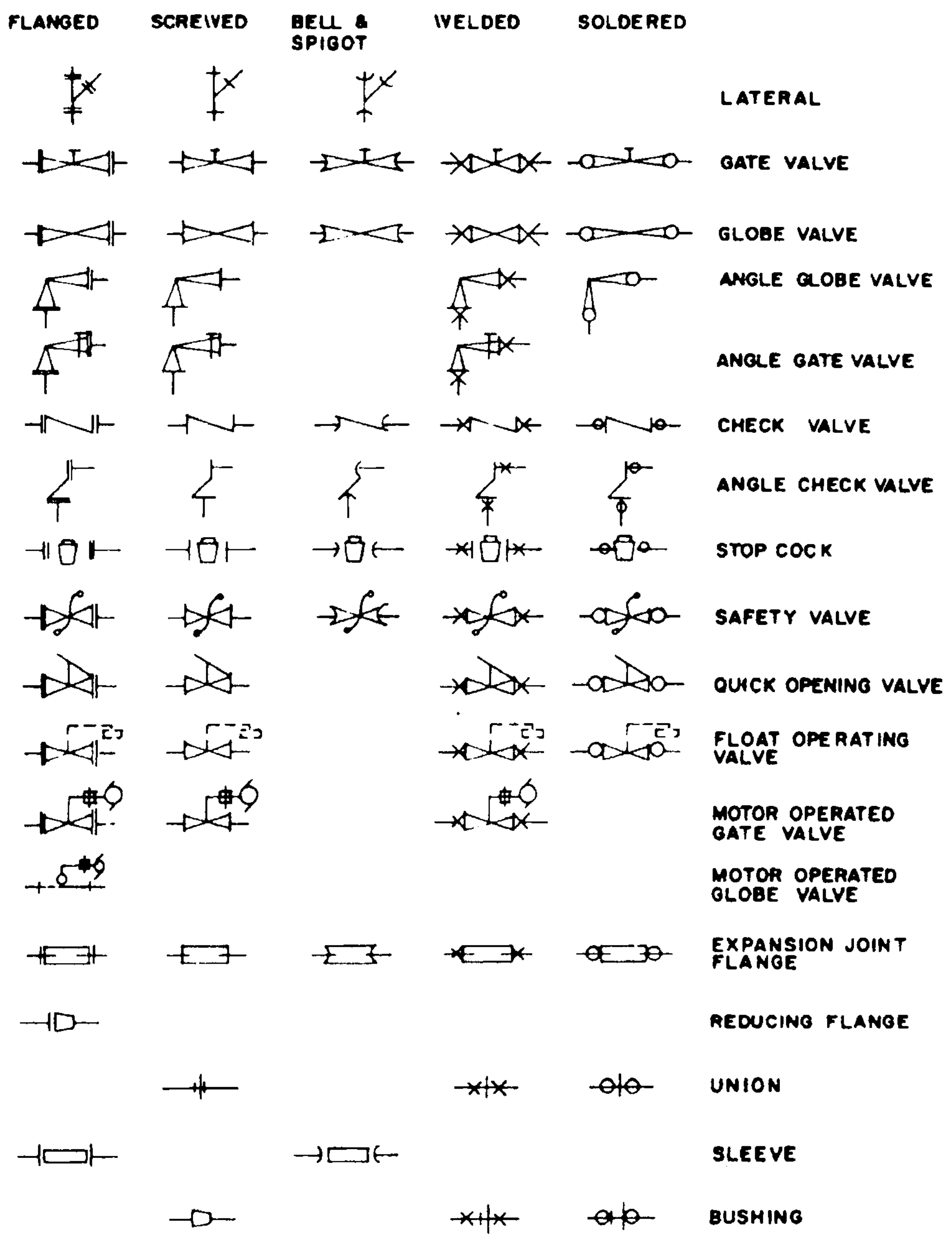
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8.18.0 Symbols for Pipe Fittings and Valves

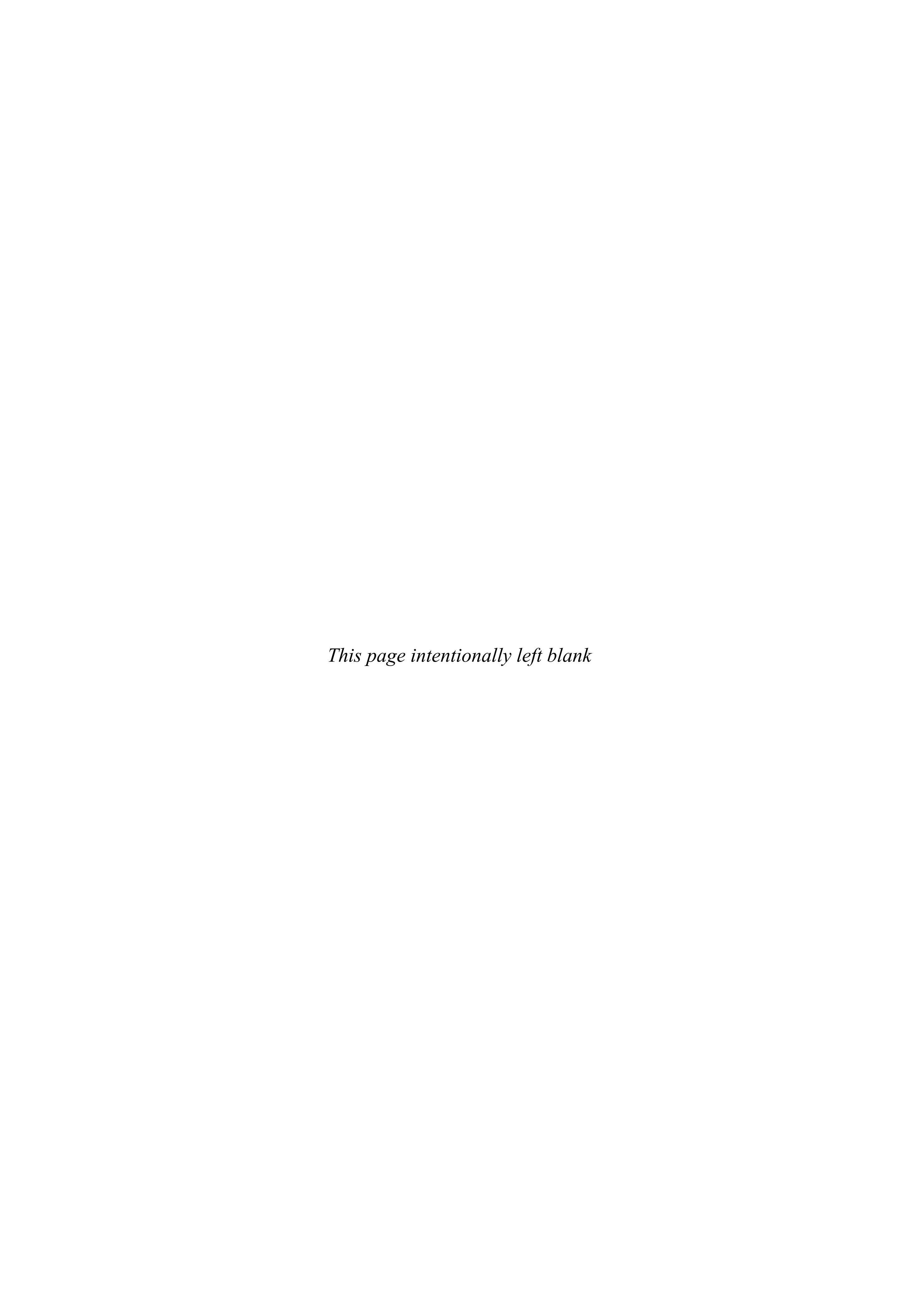


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8.18.0 Symbols for Pipe Fittings and Valves (Continued)



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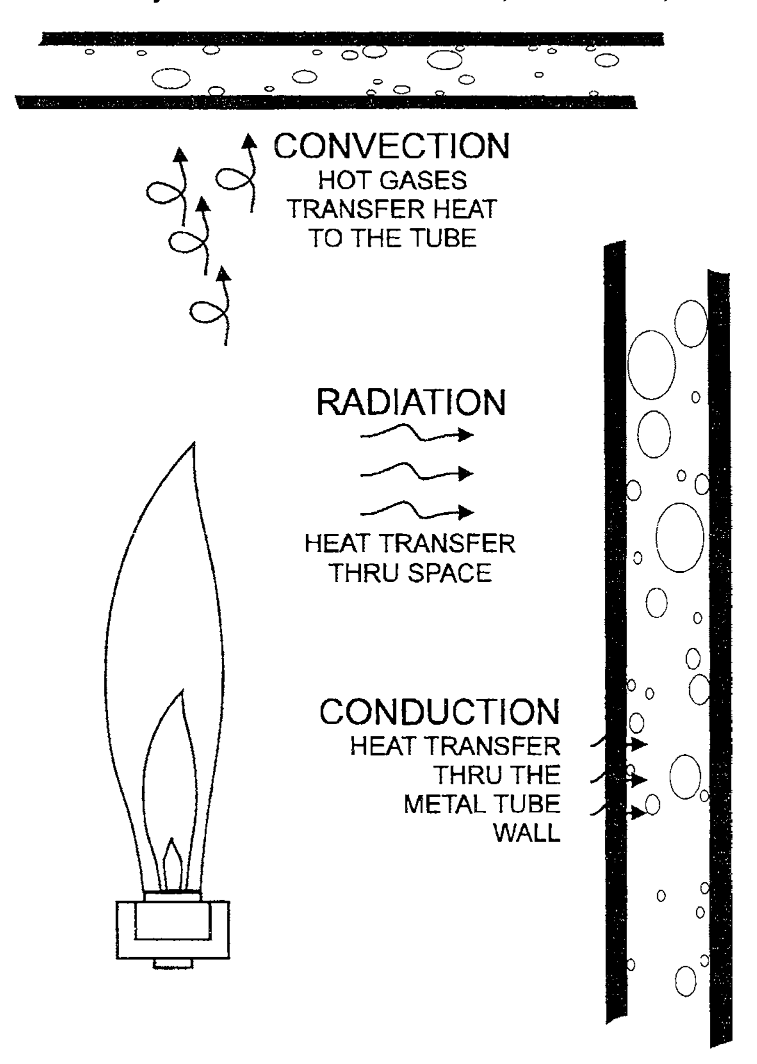
9

Mechanical Systems and Equipment

Contents

9.0.0 Heating Equipment

9.0.1 Heat Transfer by Three Methods: Radiation, Convection, and Conduction



Source: State of California, Environmental Protection Agency, Compliance Assistance Program, *A Guide to Boilers*, 1997.

9.0.2 Radiation

This is the transfer of heat through space from a hot object to a cool one. The transfer of heat from our sun to the earth is a perfect example of radiation. The heat travels on electromagnetic waves and travels until absorbed by another object.

9.0.3 Conduction

This is heat transfer from a hot object that touches a cooler one or heat that is transferred from the hot side of an object to the cool side of that object. The rate of heat transferred increases as the temperature difference increases.

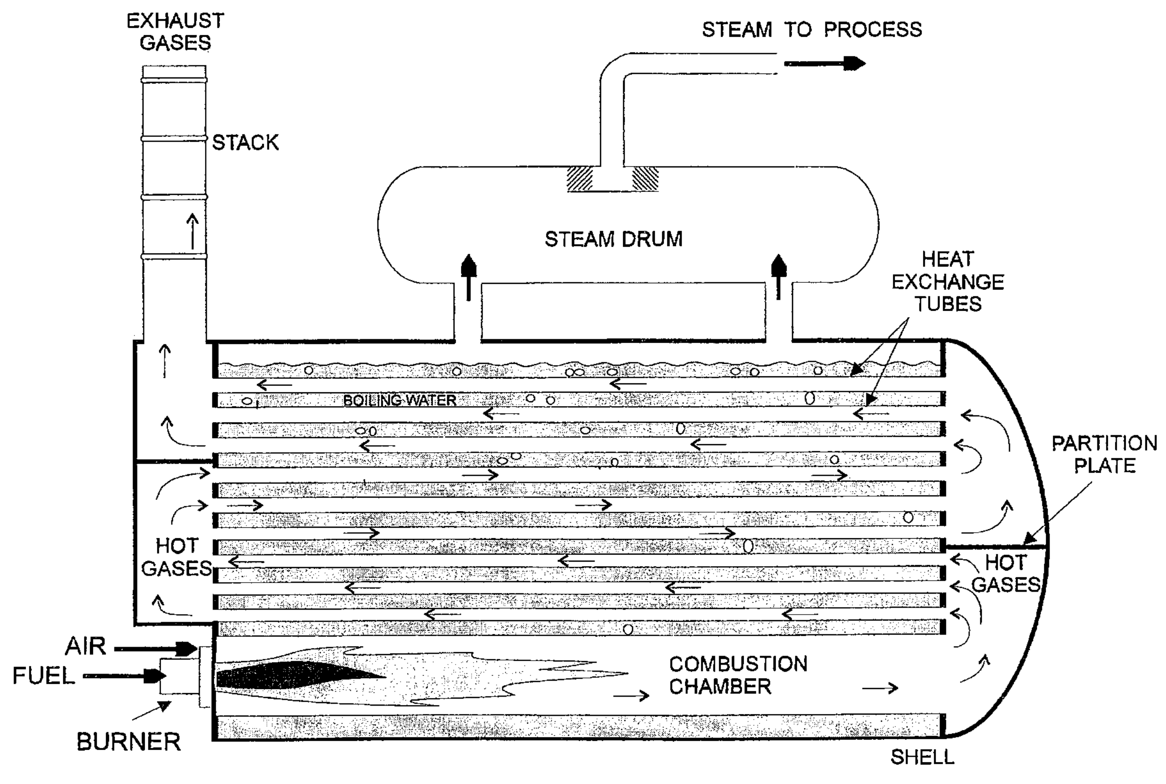
9.0.4 Convection

This source of heat is created by a flowing liquid.

9.1.0 Fire Tube Boilers

Also known as shell boilers, fire tube boilers are generally found in small or medium size boiler applications. Fire or hot gases are directed through internal tubes within the boiler shell and these tubes are surrounded by water. Gases pass through the tubes several times and heat the water in the shell before being exhausted out the stack.

9.1.1 Fire Tube Boiler Schematic

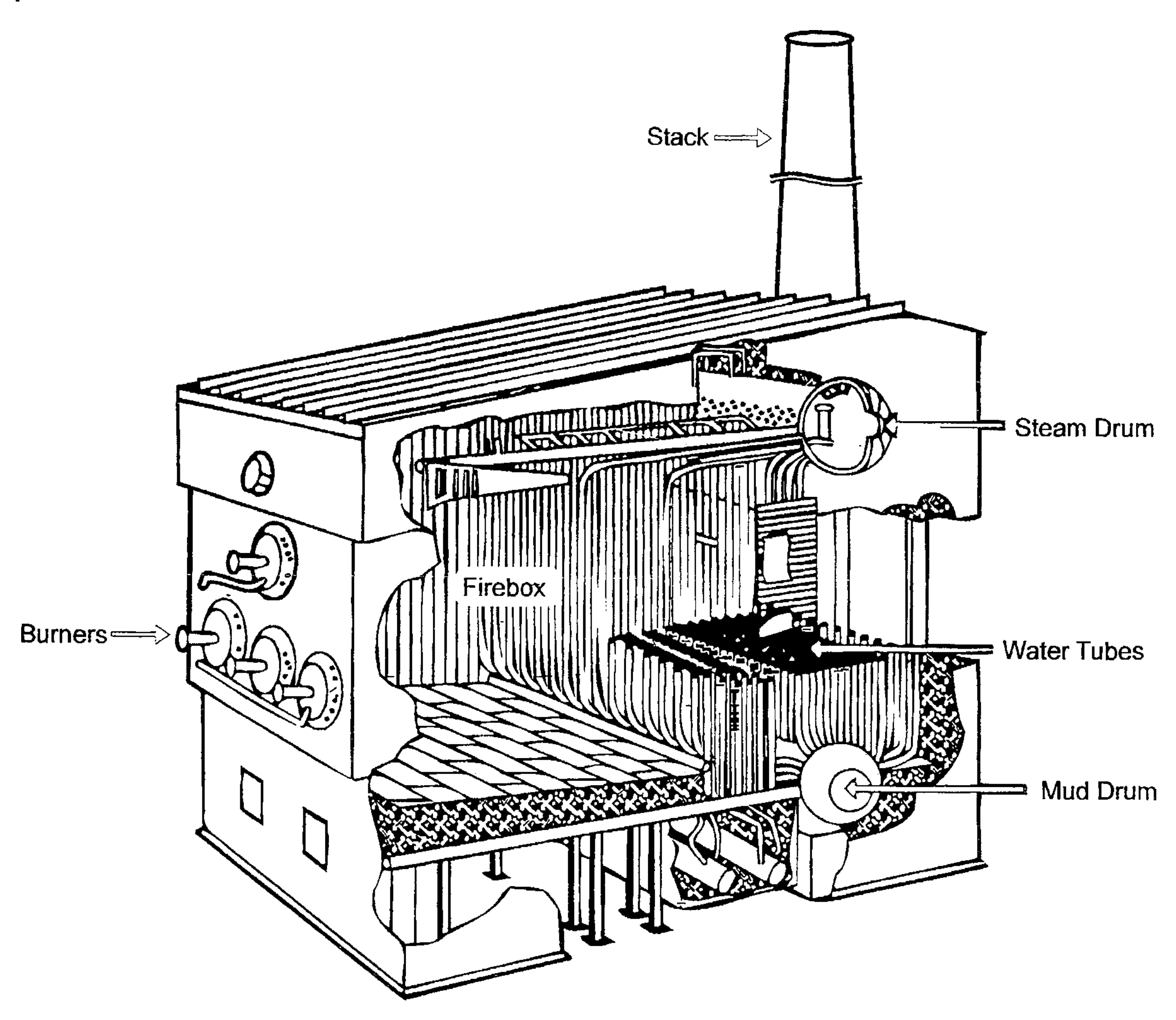


Source: State of California, Environmental Protection Agency, Compliance Assistance Program, *A Guide to Boilers*, 1997.

9.2.0 Water Tube Boiler

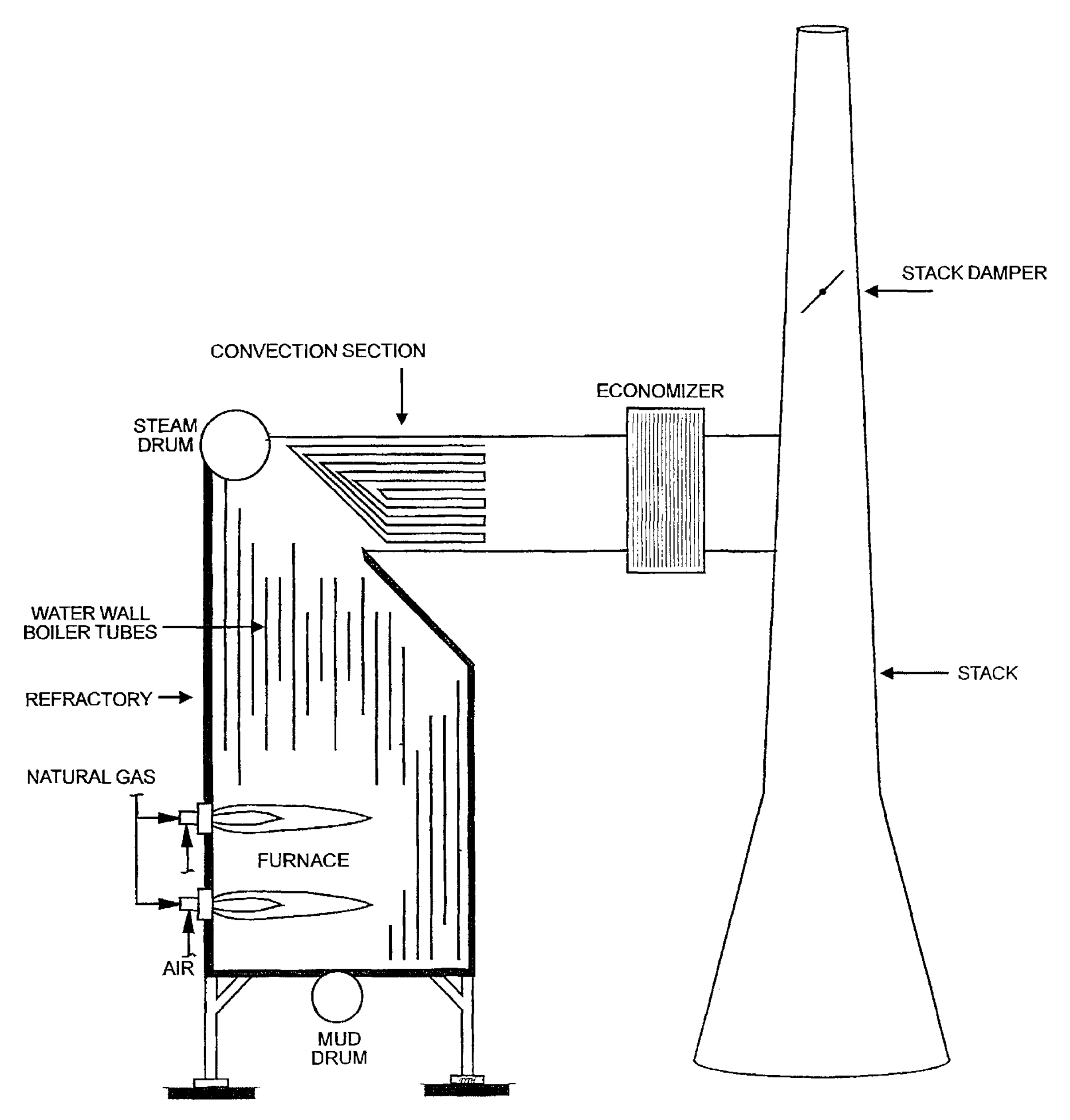
Fire or hot gases are directed around the outside of vertical tubes containing water residing within the shell of this boiler. Steam and water separate at the top of the drumlike component, and the sludge is collected in a collection point at the bottom of the boiler, better known as a mud drum.

9.2.1 Simple Water Tube Boiler



Source: State of California, Environmental Protection Agency, Compliance Assistance Program, *A Guide to Boilers*, 1997.

9.2.2 Gas-Fired Water Tube Boiler with an Economizer

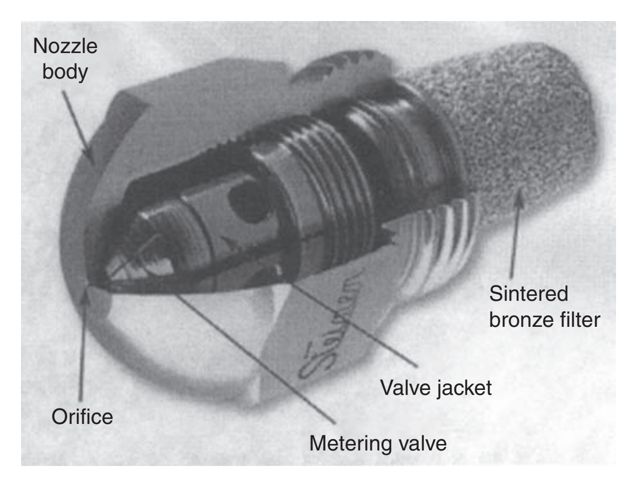


Source: State of California, Environmental Protection Agency, Compliance Assistance Program, *A Guide to Boilers*, 1997.

9.3.0 Oil Burners

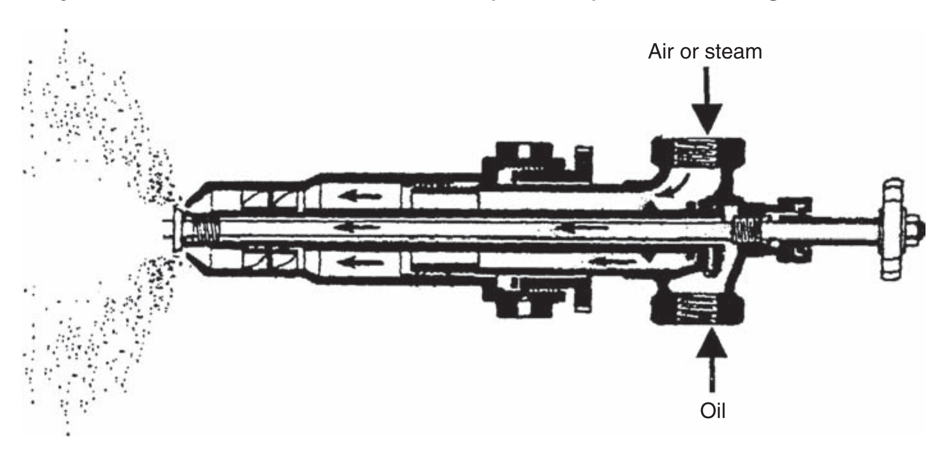
All oil burners have the same basic design. An electric motor operates an oil pump and an air supply generated by a fan. Air from the fan is directed into a blast tube at the end of which is a nozzle spraying oil into the chamber under pressure. As the oil is released through the tip of the nozzle under pressure, it atomizes into a fog which is ignited by an electric spark. As the spark jumps across a set of electrodes placed in front of the nozzle, it is blown onto the oil spray. This electric spark is generated by a transformer boosting the voltage to as high as 10,000 V.

9.3.1 A Key Component—the Spray Nozzle



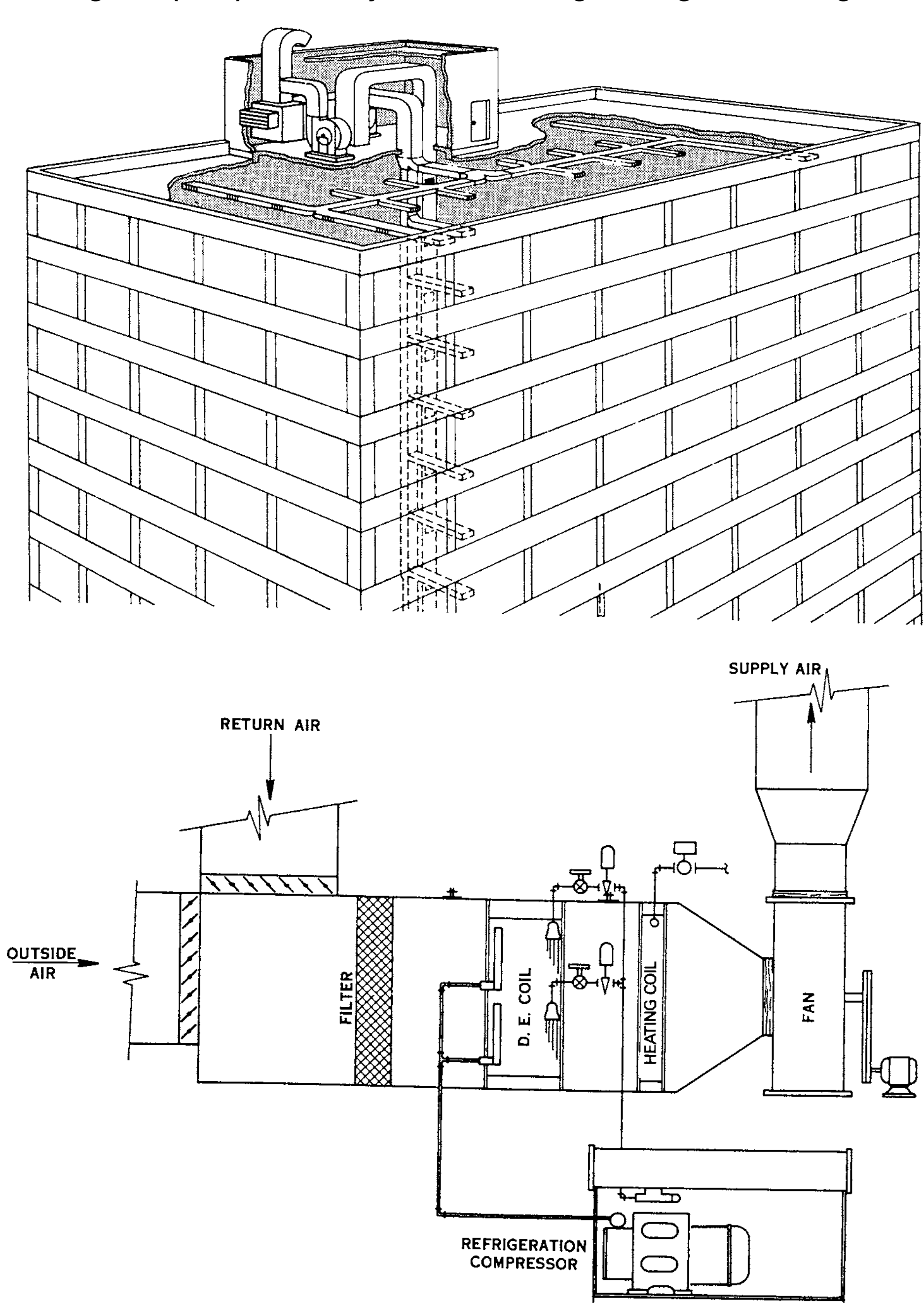
Source: Wikipedia.

9.3.2 Cutaway Section of an Oil Burner Nozzle (Oil Gun) Air-Atomizing Fuel and Air or Steam



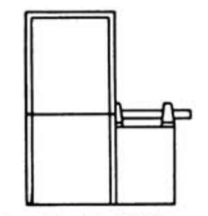
Source: State of California, Environmental Protection Agency, Compliance Assistance Program, *A Guide to Boilers*, 1997.

9.4.0 Air Handling Unit (AHU) Central System Combining Heating and Cooling

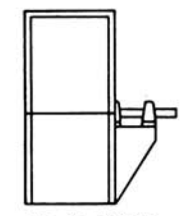


By permission, The Trane Company, La Crosse, Wisconsin.

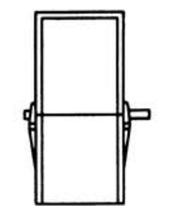
9.4.0.1 Air Transport via a Ducted Supply System



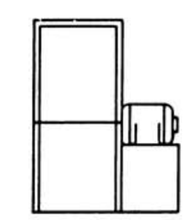
Arr. No. 1, SWSI
Belt or direct drive. Wheel overhung. Two bearings on base.



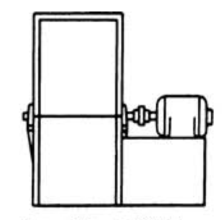
Arr. No. 2, SWSI
Belt or direct drive. Wheel overhung. Bearings in bracket supported by fan housing.



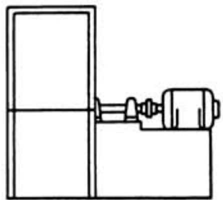
Arr. No. 3, SWSI
Belt or direct drive. One bearing on each side and supported by fan housing. Not recommended in wheel size 27″ or smaller.



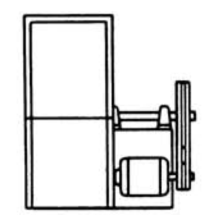
Arr. No. 4, SWSI
Direct drive. Wheel overhung on prime mover shaft. No bearings on fan. Base or equivalent for prime mover.



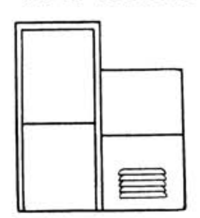
Arr. No. 7 SWSI
Belt or direct drive. Arr. No. 3 plus base for prime mover. Not recommended in wheel size 27″ or smaller.



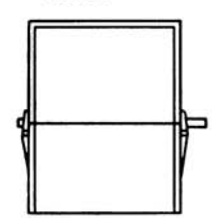
Arr. No. 8, SWSI
Belt or direct drive. Arr. No. 1 plus base for prime mover.



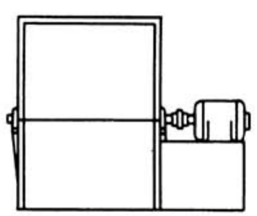
Arr. No. 9, SWSI
Belt drive. Arr. No. 1 designed for mounting prime mover on side of base.



Arr. No. 10, SWSI
Belt drive. Wheel overhung. Two bearings on angle iron frame with motor mounted underneath.



Arr. No. 3, DWDI
Belt or direct drive. One bearing on each side and supported by fan housing.



Arr. No. 7, DWDI
Belt or direct drive. Arr. No. 3 plus base for prime mover.

FIGURE 9-EE

DRIVE NOMENCLATURE

Single Width or Double Width Fan

The available space, duct connections, air temperature and degree of air contamination must all be considered in choosing an SW or DW fan. The cost of a DW fan will generally be less than an equivalent SW fan for the same duty. However, the DW is not used normally when inlet duct connections must be made or when bearings must be out of the air stream.

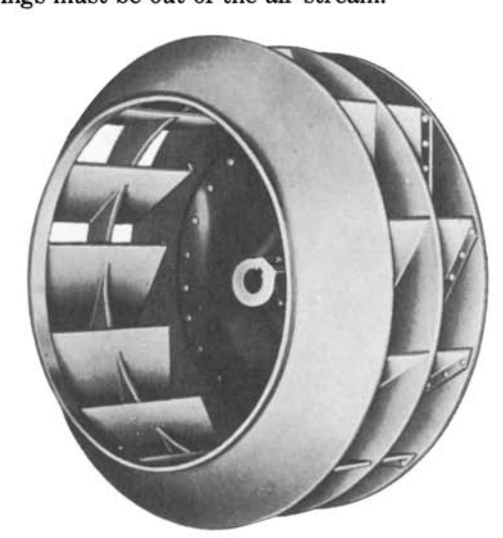


FIGURE 9-FF

DOUBLE WIDTH FAN WHEEL

Figure 9-FF illustrates a double width backwardly inclined fan wheel.

Fan Inlet and Discharge Conditions

The rated capacity of a fan can be achieved only if it is installed properly in the field. This includes unrestricted and uniform airflow to the fan inlet and proper discharge connections at the fan outlet.

At the fan inlet, the following conditions will seriously reduce the fan capacity:

1. Spinning air stream.
2. Non-uniform air distribution.
3. Insufficient space between fans or from the fan inlet to a wall.

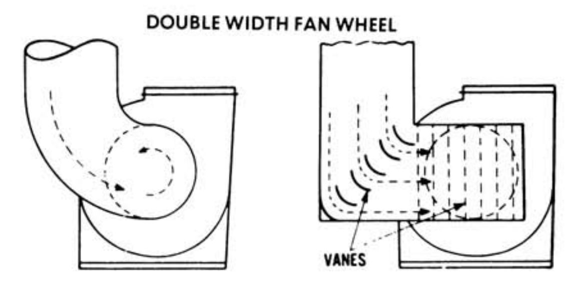


FIGURE 9-GG

COMPOUND CURVE ON FAN INLET DUCT (LEFT) CAUSES SPIN. VANES IN ELBOW AND AT FAN INLET ELIMINATE SPIN.

By permission, The Trane Company, La Crosse, Wisconsin.

9.4.1 Single-Path and Dual-Path Air Handling Systems

Typical Application Considerations

The first things to consider when selecting an air handler for any given application include:

- *Design*. What overall system design best suits the required function?
- *Arrangements*. What is the best module arrangement for the specified function and layout?
- *Components*. Which components should be selected to support the function, layout, and arrangement of the application?

Air-Handling System Design

After determining the required airflows and functions for a particular application, the HVAC designer must determine which one of two path layouts for outdoor air best serves the application: single-path or dual-path.

Single-Path Design (Figure 41)

Single-path AHUs rely on one outdoor air path. Depending on application requirements, that path may provide ventilation air only or both ventilation air and economizing air for natural, non-mechanical cooling. Components for filtering and tempering the air are arranged in series. The single-path layout can accommodate passive or powered return- and/or exhaust-air paths as well as energy recovery.

Dual-Path Design (Figure 42)

Dual-path AHU layouts provide two air paths. Like a single-path design, dual-path designs can incorporate basic outdoor air, recirculation, exhaust-air, and energy-recovery functions. However, one path is dedicated to handling ventilation air to specifically address ASHRAE Standard 62.1 requirements. Each path is provided with its own air treatment components such as filters and heating and cooling coils.

Figure 41. Single-path design

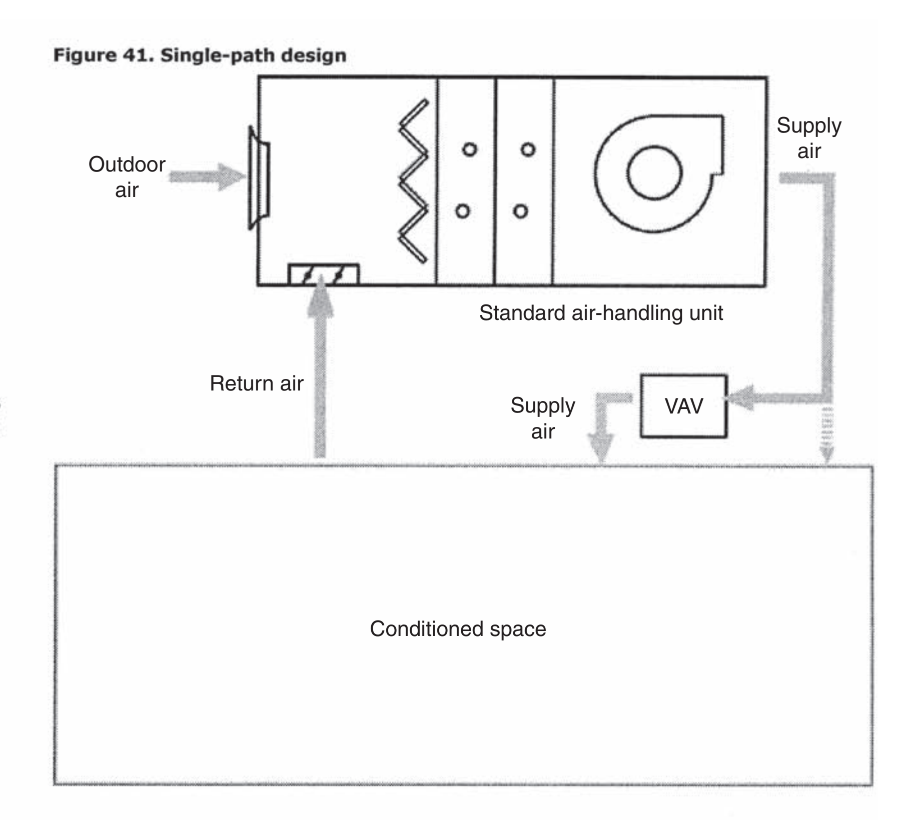
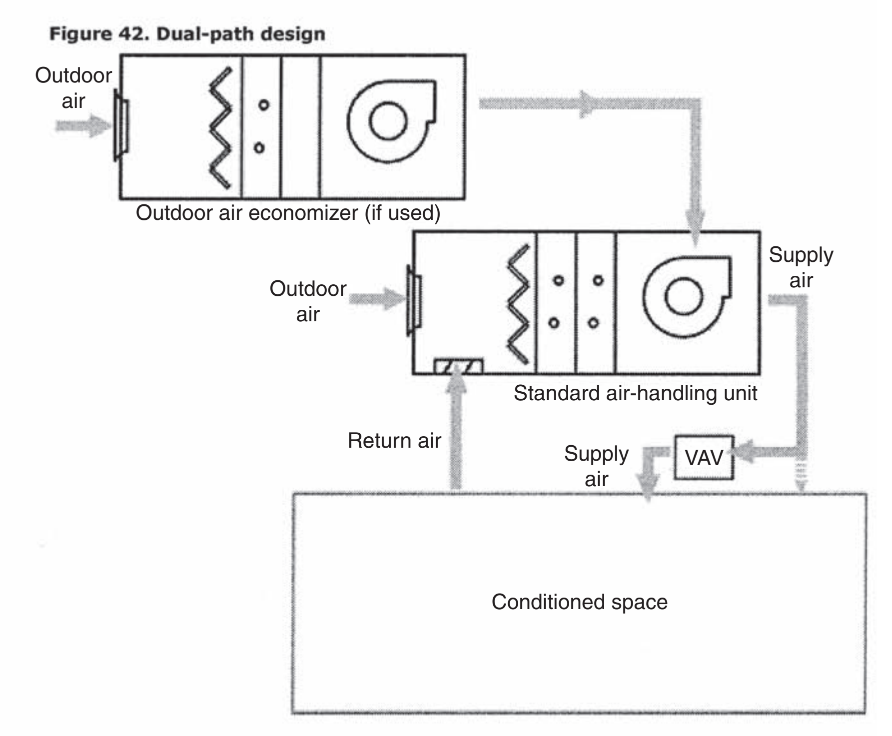


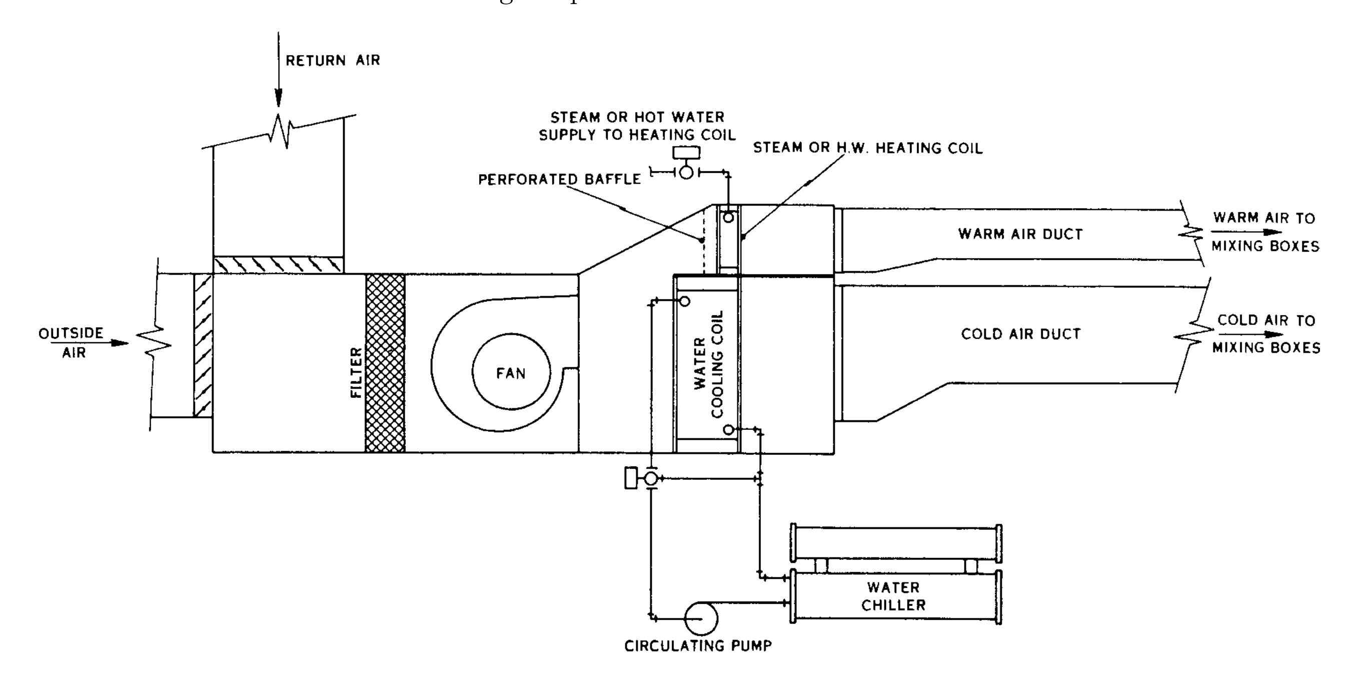
Figure 42. Dual-path design



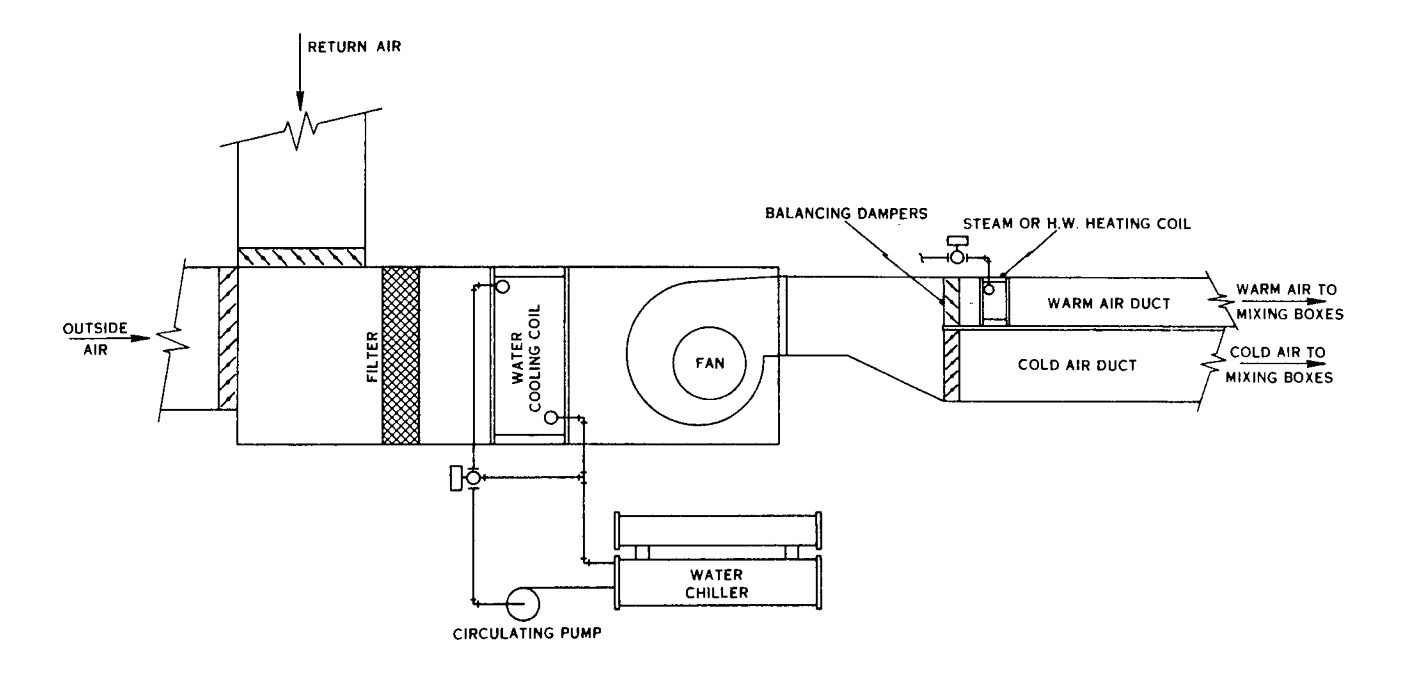
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9.4.2 Two Types of Central Fan, Cooling and Heating Coils

One fan has a set of balancing dampers and controls.



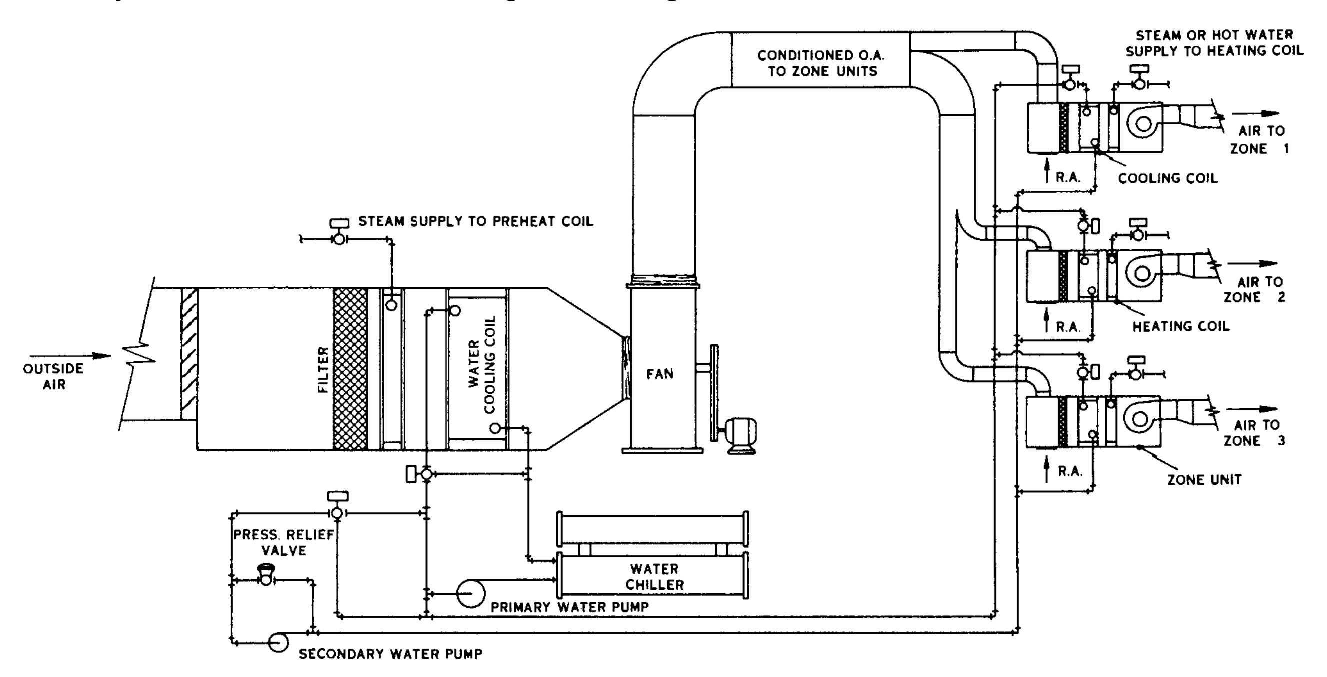
SYSTEM WITH CENTRAL FAN, WATER COOLING COIL, STEAM OR HOT WATER COIL, FILTERS, DOUBLE-DUCT AIR DISTRIBUTION, MIXING BOXES FOR CONDITIONED SPACES REFRIGERATION UNIT FOR CHILLING WATER, OR A REFRIGERATION COMPRESSOR AND DIRECT EXPANSION COOLING COIL FOR COOLING AIR AND CONTROLS.



SYSTEM WITH CENTRAL FAN, WATER COOLING COIL, STEAM OR HOT WATER COIL, FILTERS, DOUBLE-DUCT AIR DISTRIBUTION MIXING BOXES FOR THE CONDITIONED SPACES, REFRIGERATION UNIT FOR CHILLING WATER, OR A REFRIGERATION COMPRESSOR AND A DIRECT EXPANSION COOLING COIL FOR COOLING THE AIR, A SET OF BALANCING DAMPERS AND CONTROLS.

By permission, The Trane Company, La Crosse, Wisconsin.

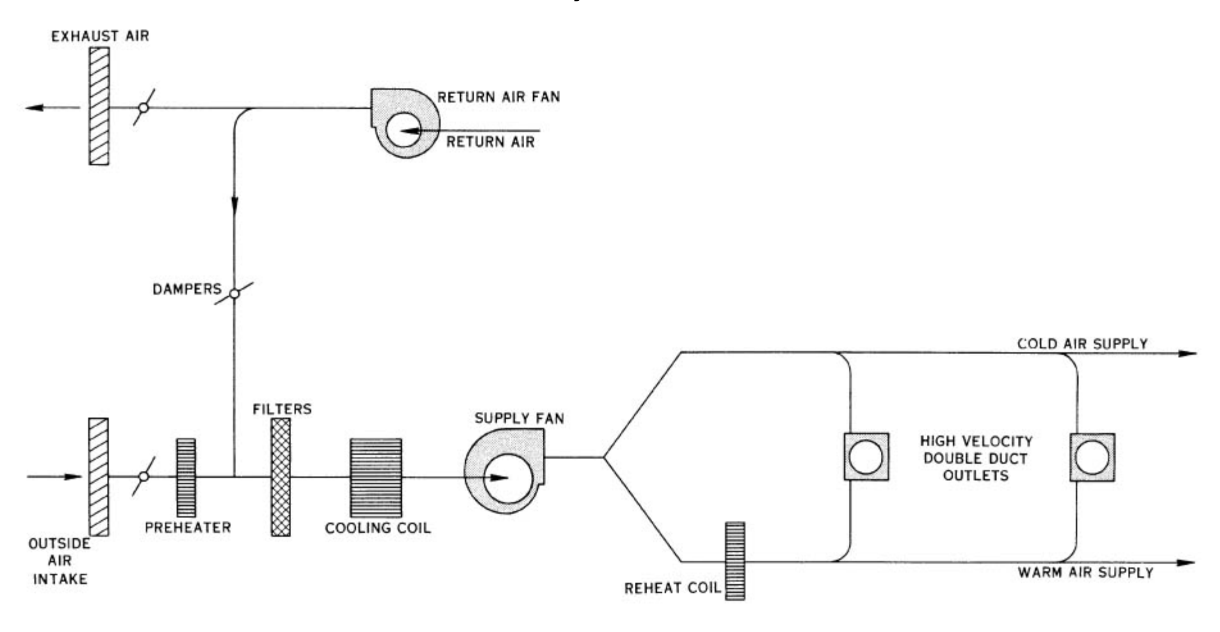
9.4.3 System with Central Fan, Cooling and Heating Coils, Outside Air



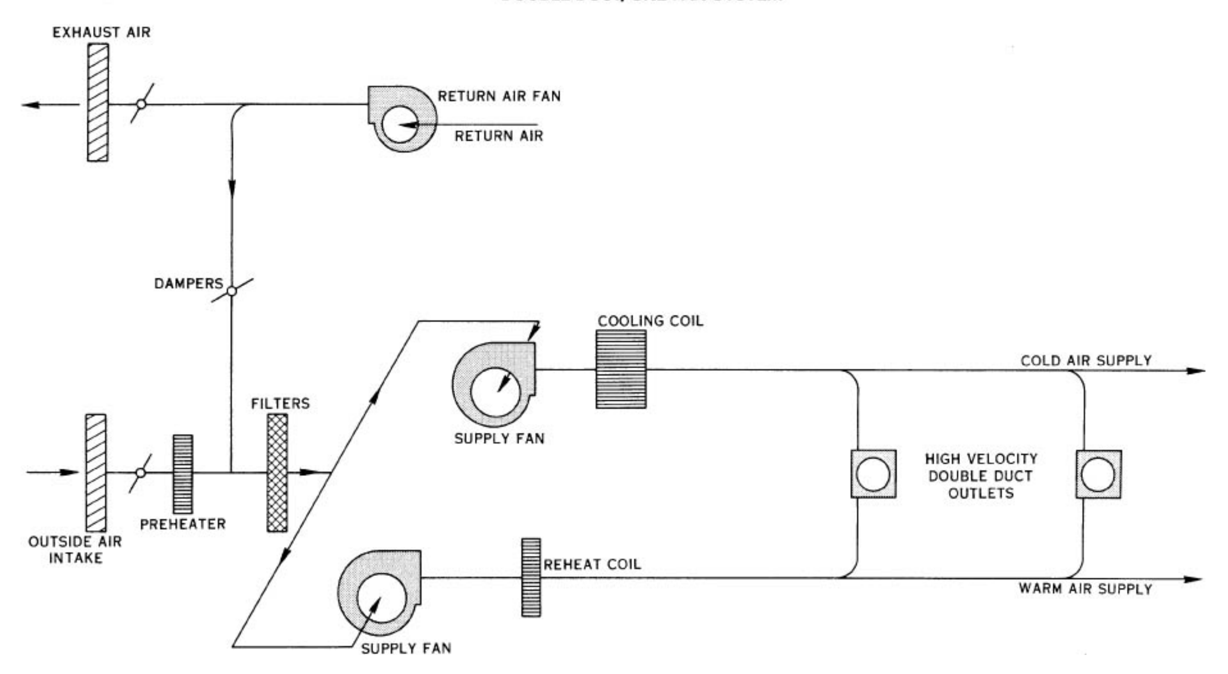
SYSTEM WITH CENTRAL FAN UNIT WITH PREHEAT COIL, COOLING COIL AND FILTERS FOR SUPPLYING CONDITIONED OUTSIDE AIR TO ZONE UNITS WHICH INCLUDE A FAN, COOLING COIL, HEATING COIL, FILTERS AND DISTRIBUTING DUCT WORK. OTHER COMPONENTS ARE A REFRIGERATION UNIT, PRIMARY AND SECONDARY CIRCULATING PUMPS AND CONTROLS.

By permission, The Trane Company, La Crosse, Wisconsin.

9.4.4 Double Duct—One-Fan and Two-Fan Systems



DOUBLE-DUCT, ONE-FAN SYSTEM

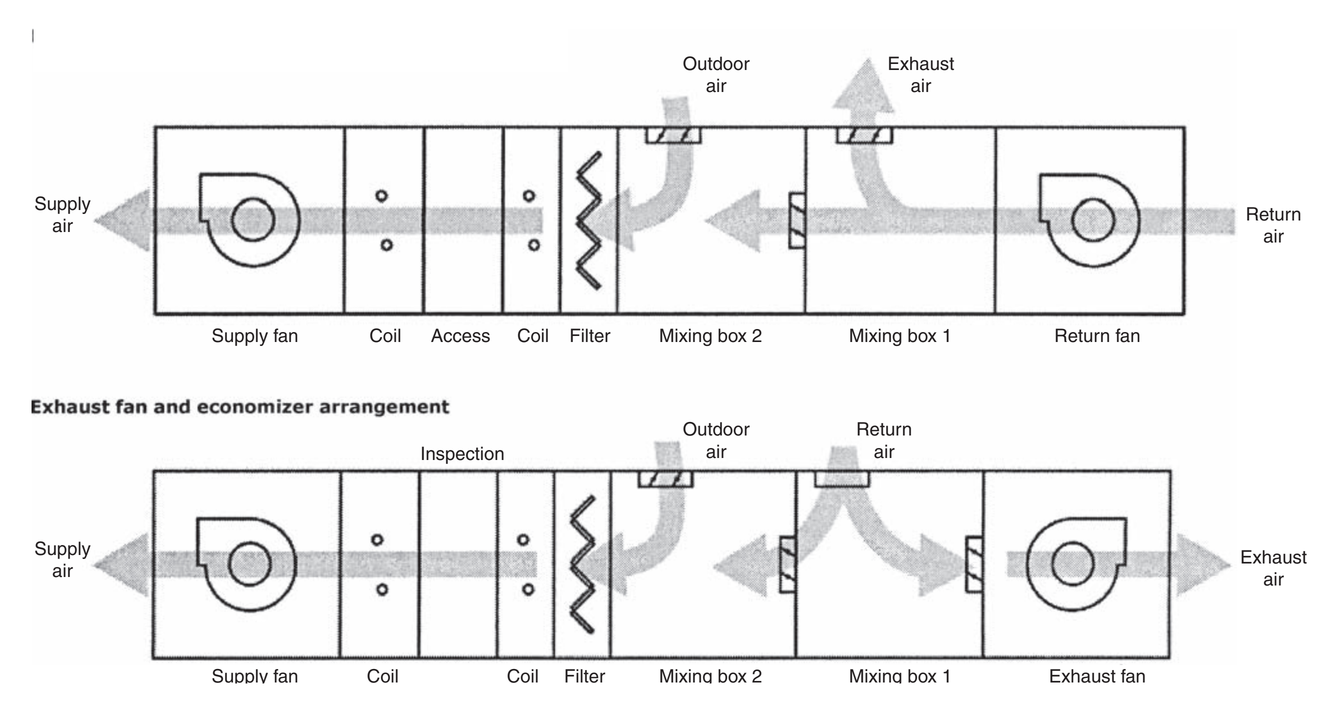


DOUBLE-DUCT, TWO-FAN SYSTEM

Up to this time, the discussion on ducts has been confined to a single supply duct and a single return duct. There is also the possibility of using two supply ducts and one return duct. This would be similar to the three-pipe water arrangement, in that one duct supplies warm air and one supplies cold air with the return duct carrying the mixture of the two back to the fan. This arrangement is called a double-duct or dual-duct arrangement.

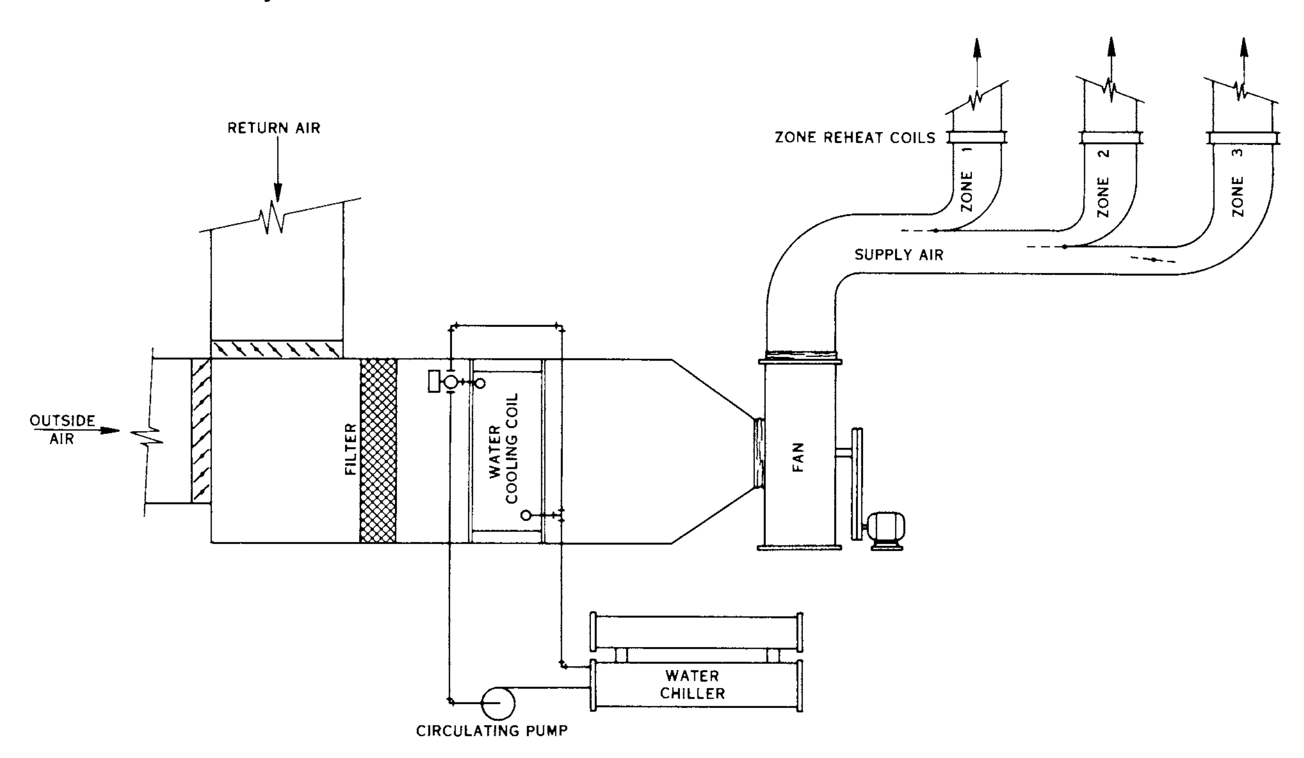
By permission, The Trane Company, La Crosse, Wisconsin.

9.4.5 Return Air and Economizer Arrangement



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9.4.6 Central Fan System with Zone Reheat Coils



SYSTEM WITH CENTRAL FAN, WATER COOLING COIL, FILTERS, DISTRIBUTING DUCTWORK, ZONE REHEAT COILS, REFRIGERATION UNIT FOR CHILLING COLD WATER, CIRCULATING PUMP AND CONTROLS.

By permission, The Trane Company, La Crosse, Wisconsin.

9.4.7 Energy Recovery Schematics

Energy Recovery with Air-to-Air, Fixed-Plate Heat Exchangers (Figure 56)

This arrangement is usually employed to recover sensible energy. It is more cost-effective in smaller units (less than 10,000 cfm). It is also used in cases where cross-flow issues are critical.

The exchanger preheats the supply air during winter and precools the supply air during summer. The optional frost-protection damper mounted on the outdoor-air face of the heat exchanger closes if the temperature drops below freezing at the cold corner of the exchanger (the leaving-exhaust-air corner, toward the outdoor air). The frost-protection damper reduces the recovery effectiveness of the heat exchanger and minimizes the amount of outdoor airflow at the cold corner as well as the possibility of frost forming on the exchanger.

Also, if the air handler is designed to deliver cold supply air, an optional face-and-bypass damper mounted on the exhaust side of the exchanger is needed to prevent the heat exchanger from recovering too much energy from the warm exhaust air when it is not needed. Using exhaust air energy recovery can significantly decrease the cooling and heating load on the system.

Trane's Energy Recovery Performance (ERP) program can calculate total-energy wheel performance and determine if frost protection is needed. Contact your local Trane sales representative for more information about the ERP program. (See Trane engineering bulletin CLCH-PRB012-EN for more information.

Figure 55. Energy recovery with a runaround coil loop

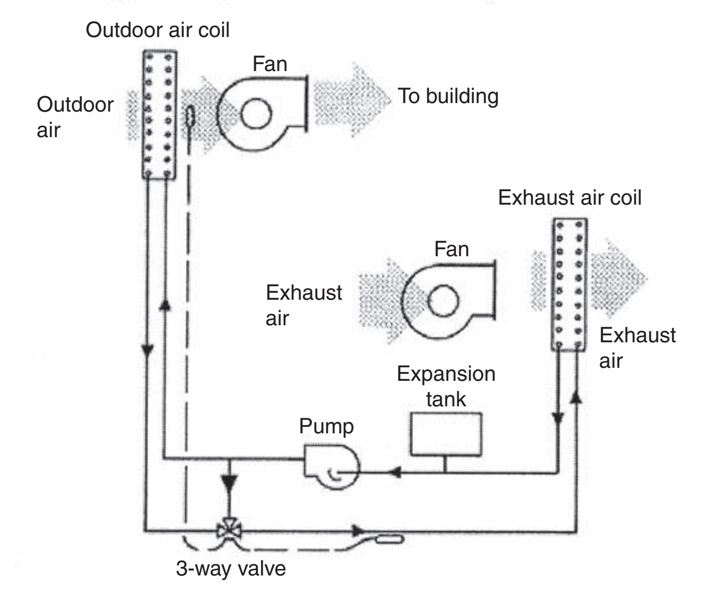
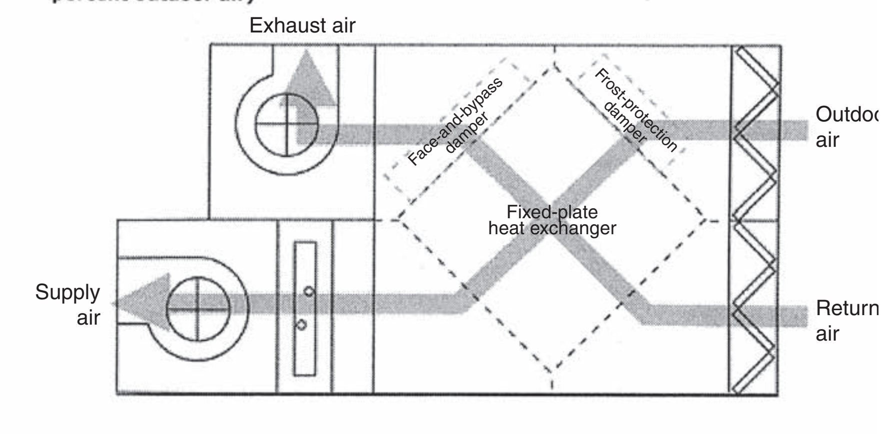
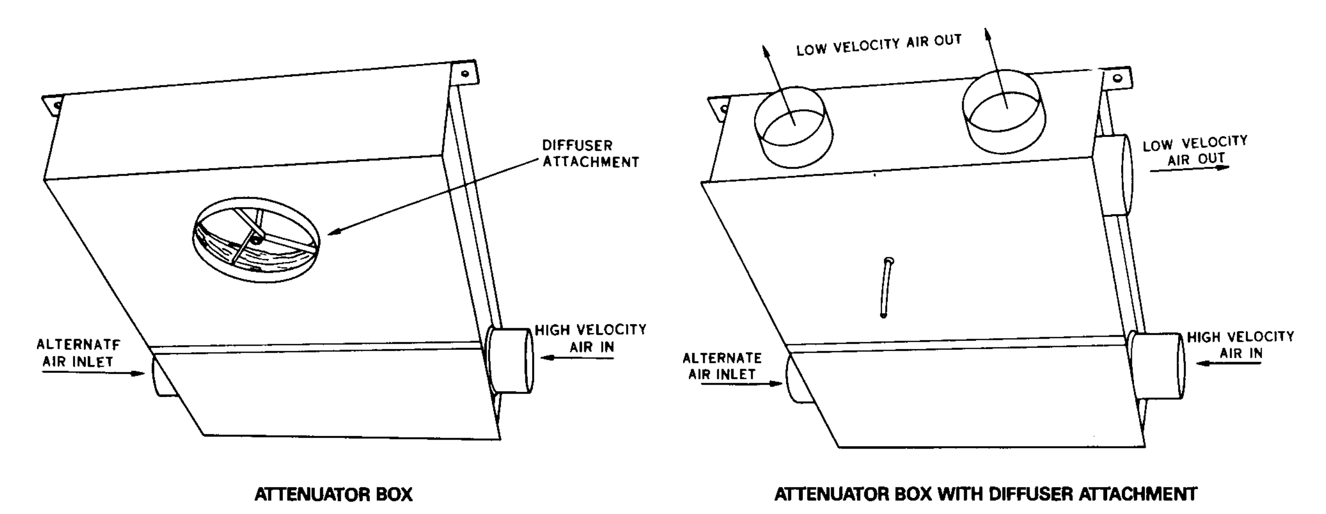


Figure 56. Energy recovery with an air-to-air, fixed-plate heat exchanger (100 percent outdoor air)



By permission, The Trane Company, La Crosse, Wisconsin.

9.4.8 An Attenuator Box and One with a Diffuser Attached



ATTENUATOR BOX **ATTENUATOR BOX WITH DIFFUSER ATTACHMENT**

By permission, The Trane Company, La Crosse, Wisconsin.

9.4.9 Protecting Coils from Freezing

Low-limit sensor

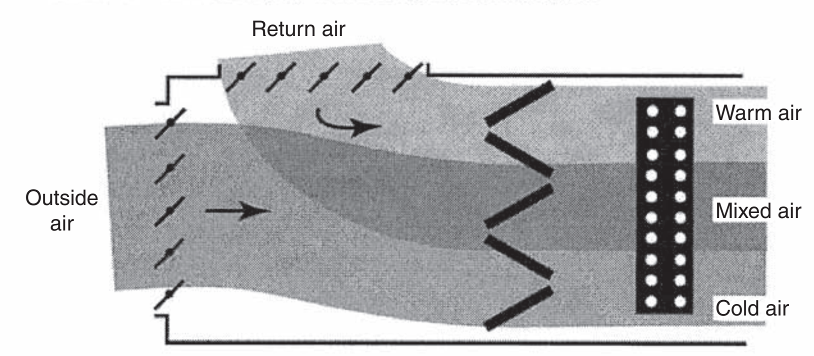


Bringing more outdoor air into the air handler to satisfy the ventilation requirements of ASHRAE Standard 62.1 increases the likelihood of air stratification. If a layer of freezing air moves through the air handler, it can damage unprotected, hydronic cooling and heating coils. Traditional freeze protection includes a low-limit thermostat (installed on the face of the cooling coil) that trips when it detects a dangerously low air temperature. That stops the supply fan, closes the outdoor air damper, and ultimately degrades the building IAQ.

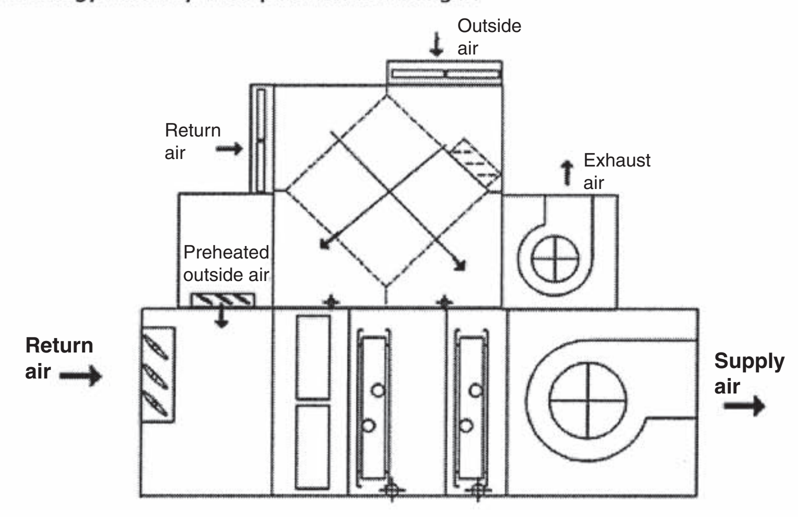
It is important to design the air handler so that it effectively treats the required amount of outdoor air—regardless of temperature—without risking coil damage, tripping the low-limit thermostat, or compromising IAQ. Trane has several means of providing coil protection. Choose the technique that best suits the application requirements.

- *Drain the coils.* This approach necessitates vent and drain connections on every coil, plus shutoff valves to isolate them from the chiller(s).
- Add glycol and an inhibitor to the cooling system water. The glycol lowers the water freezing point, and the inhibitor helps to resist corrosion.
- *Introduce ventilation air downstream of the cooling coil* with dual-path or bypass techniques.
- *Preheat the outdoor air stream.* Use a traditional or integral face-and-bypass steam coil or a hot hydronic coil to raise the air-stream temperature above freezing. An energy-recovery device can also be used for this purpose, such an air-to-air, fixed-plate heat exchanger (see Figure 32).

Protect coils from freezing by addressing air stratification



Protect coils from freezing by preheating outdoor air, shown here using an energy-recovery fixed-plate heat exchanger.



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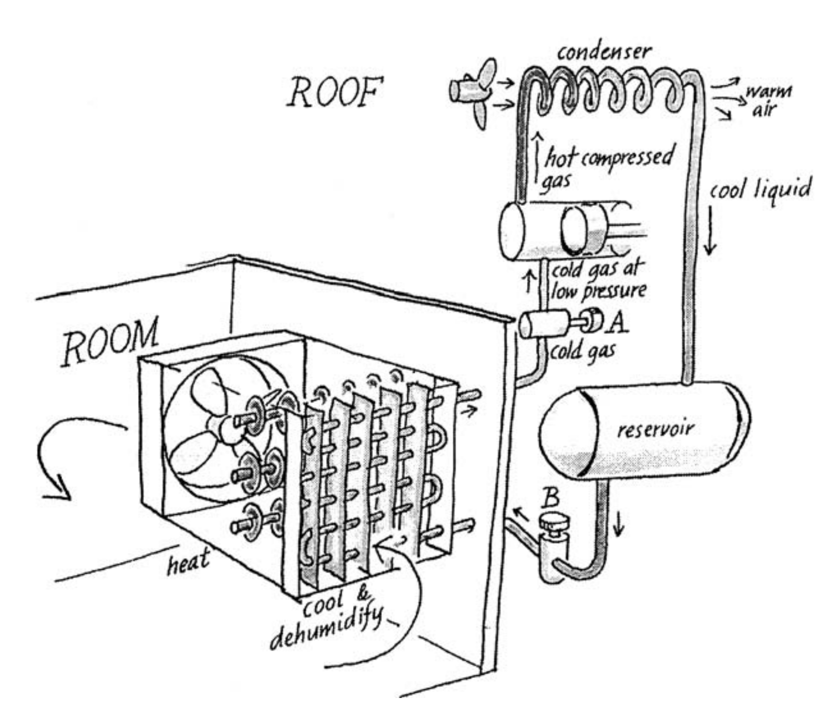
9.5.0 Air-Conditioning Equipment—a Basic Refrigerator in Reverse

Air-conditioning equipment uses the principle of evaporation to produce cold air and exhaust warm air. The evaporation cycle operates thus:

- A compressor compresses gas, a fluorocarbon, until it becomes hot.
- This hot gas travels through a set of coils that allow it to dissipate the heat and, as a result, condense into a liquid.
- This fluorocarbon liquid flows through an expansion valve, and as it evaporates, it becomes cold.
- The cold gas travels through a set of coils that allow the gas to absorb heat and cool air that is circulated through the building.

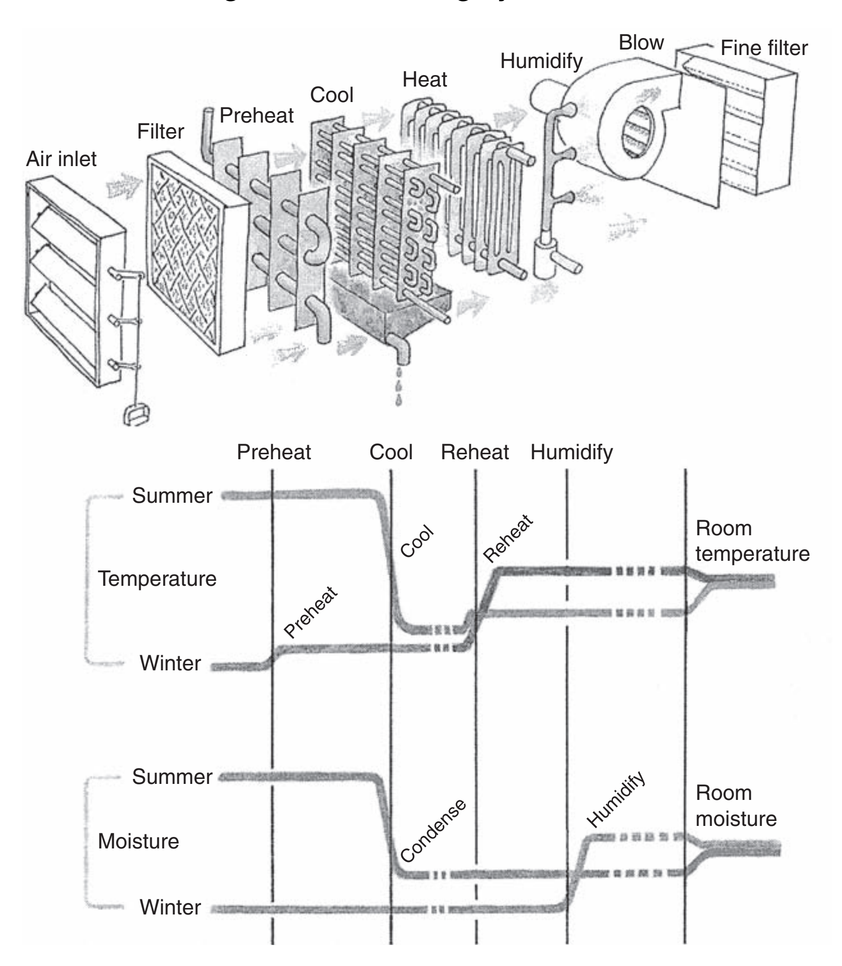
9.5.1 Simple Air-Conditioning Unit

A fan draws air from the room first through a cooling device, consisting of metal fins extending from a pipe through which cooling fluid circulates, at a rate determined by the thermostat or by the humidistat. The air next passes over a heater, usually electrical, which is energised on instructions from the room thermostat.



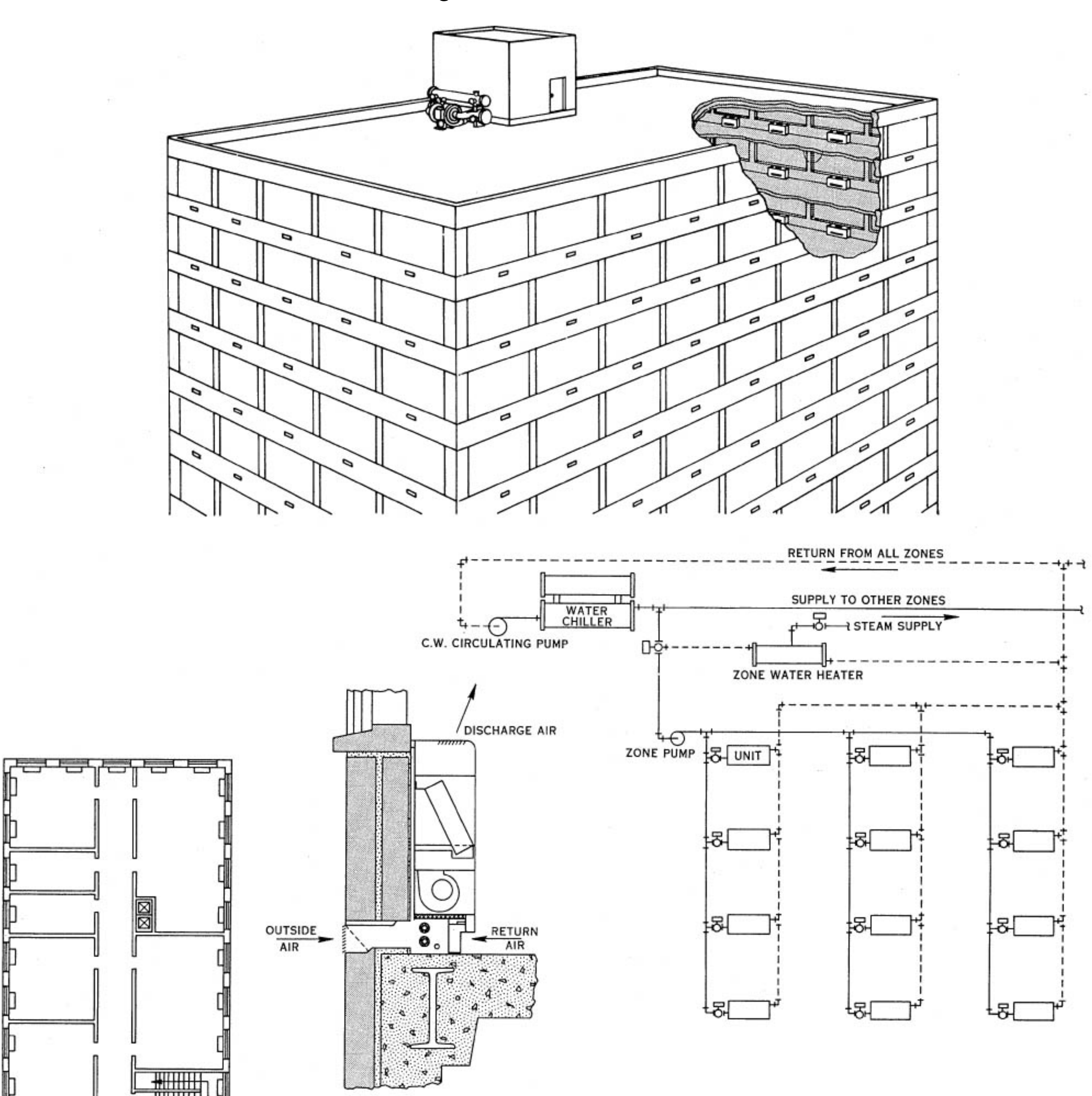
Source: Air-conditioner-Selection.com.

9.5.1.1 Schematic of a Large Air-Conditioning System



Source: Air-conditioner-Selection.com.

9.5.1.2 Schematic of Fan Coil Units Using Chilled Water to Condition Air



By permission, The Trane Company, La Crosse, Wisconsin.

9.5.1.3 Dehumidification and a Diagram of a Split Dehumidification Unit

Dehumidify

Excessive humidity in buildings can encourage mold and mildew growth and thermal discomfort. To cost effectively address these issues, first isolate the conditioned space from the unconditioned space. (See Trane applications engineering manual, *Managing Building Moisture*, SYS-AM-15.) Next, remove the humidity.

The two primary humidity sources in most buildings are people and outdoor air. In any coil-based HVAC system, it is the cooling coil that dehumidifies the air. This coil must be on and air must pass through it for dehumidification to occur. In M-Series enhanced dehumidification units, the priority for cooling coil control is humidity control. Temperature control is secondary and is generally provided by a separate reheat source.

Dehumidification can be obtained using:

- SDU (split dehumidification unit) arrangements
- CDQ™ (Cool, Dry, Quiet) units with desiccant wheels
- series, coil runaround loops
- air-to-air, fixed-plate heat exchangers

Free reheat options with dehumidification include:

- hot water heat-recovery coils
- refrigerant heat-recovery H coils

Dehumidification with a Split Dehumidification Unit (SDU) Arrangement (Figure 49)

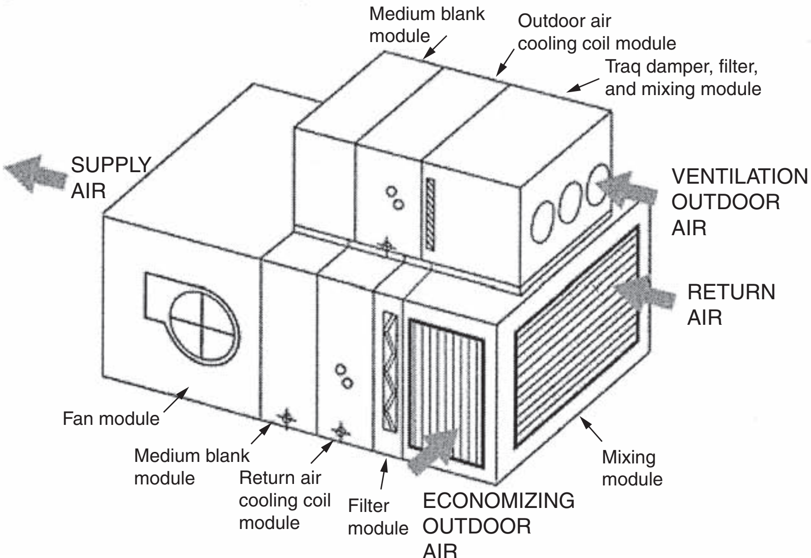
The SDU is a dual-path, return-air-bypass air handler. It consists of two units that are stacked together in a draw-thru arrangement and that share one supply fan. All of the ventilation (outdoor) air is ducted to the upper unit where it is dehumidified, typically down to 50ºF or lower.

The lower unit is sized to handle the return air needed to achieve the desired air-change rate in the space. The warmer return air in the lower unit mixes with the cooler, drier air from the upper unit. The resulting mixed air provides humidity control by achieving a sensible heat ratio (SHR) of down to 0.4, but also provides sensible reheat without using any new energy.

A vertical unit stacks the supply fan on top of a vertical coil module; the outdoor air enters the back of the fan module. This unit is shorter than the horizontal SDU.

Outdoor air economizers can also be used with an SDU. Simply add a mixing module to the return-air unit and bring outdoor air into this mixing module when conditions permit economizing.


Figure 49. Horizontal M-Series split dehumidification unit



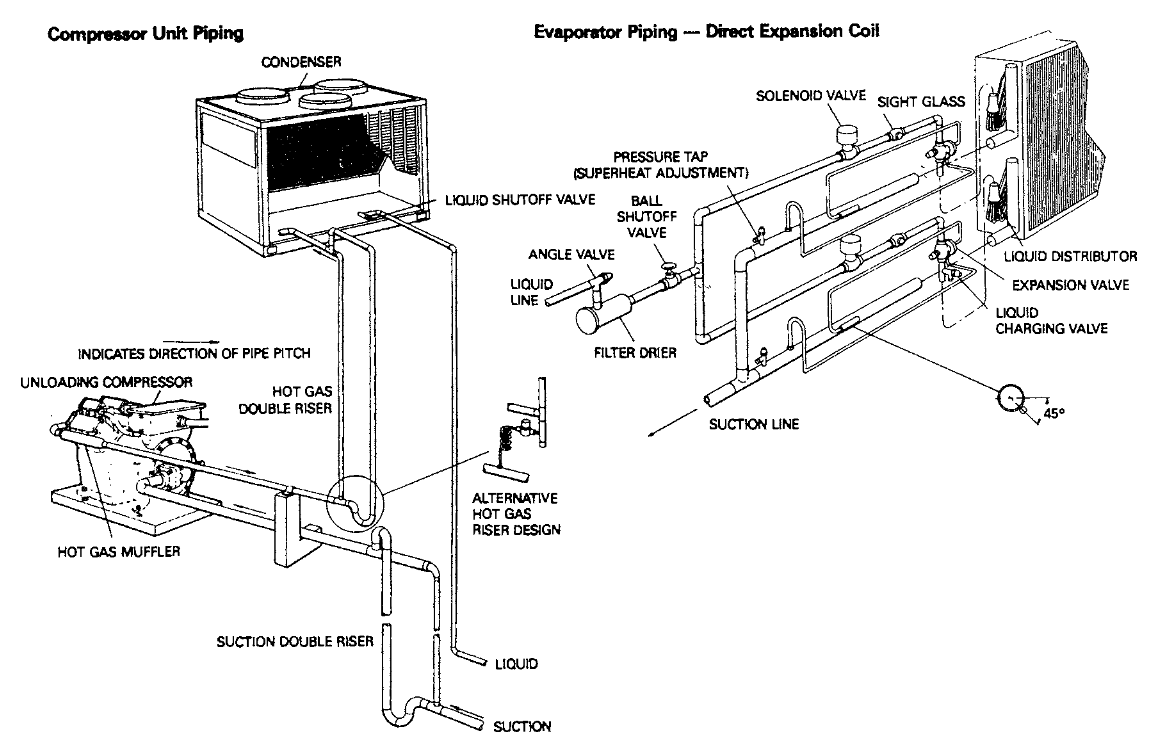
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9.5.1.4 An Air-Cooled Condenser and Typical Piping Arrangement

System Piping Suggestions

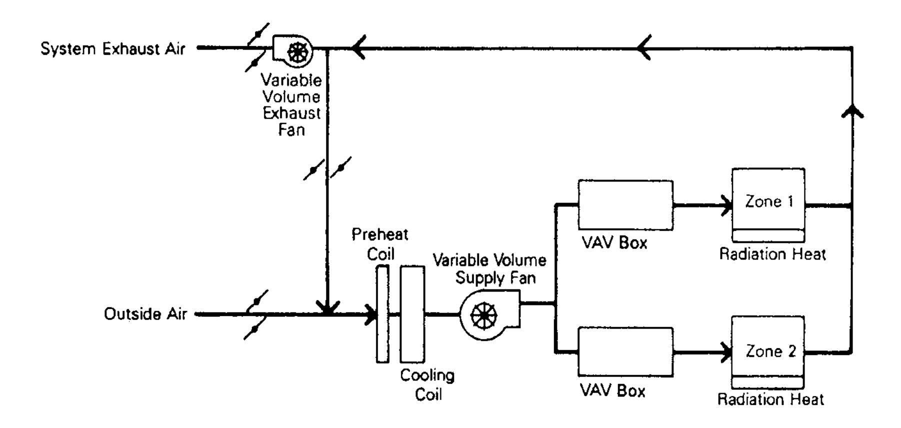
If an air conditioning system with an air-cooled condenser will operate only when the outdoor temperature is above 40 F, a simple fan cycling or multilouvered damper control is usually adequate. The shutter control will follow the system load variations closely enough so there should be neither head pressure nor starting problems. The system piping can be simple, as illustrated in the piping diagram.

As will be noted, this system does not employ the conventional liquid receiver. The air condenser has sufficient volume to hold the charge on a system where the components are reasonably close together. Since the accumulator between the condensing circuit and the subcooler of the air condenser can handle a small variation in liquid volume, this would not be considered a critically charged system.

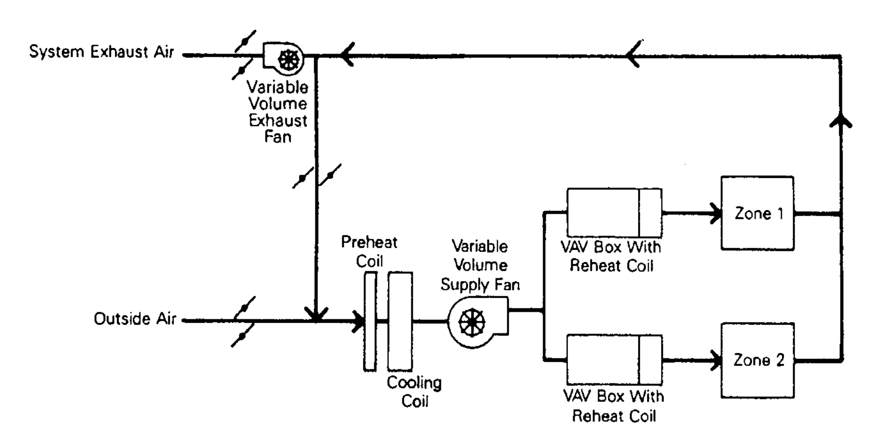


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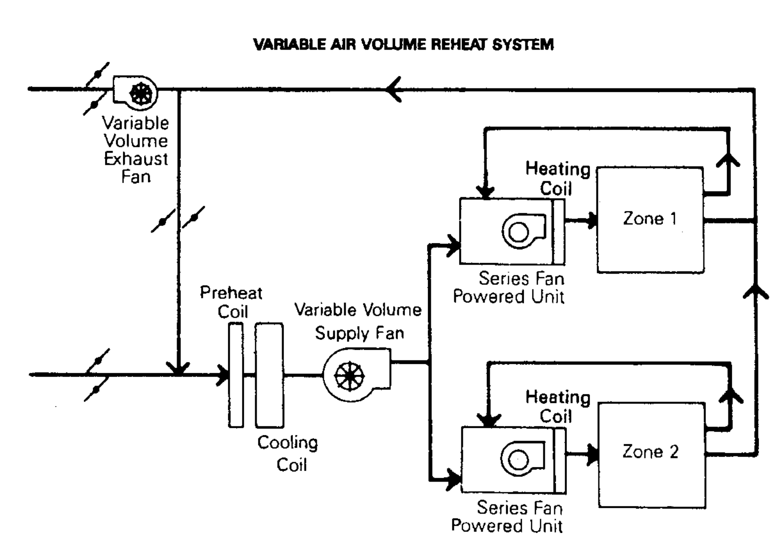
9.5.1.5 A Variable Air Volume (VAV) Fan-Powered Air Distribution Schematic



VARIABLE AIR VOLUME COOLING WITH PERIMETER RADIATION HEATING



VARIABLE AIR VOLUME REHEAT SYSTEM



By permission, The Trane Company, La Crosse, Wisconsin.

9.5.2 Air-Conditioning Refrigerant Gases

Freon is a generic name for two chemical compounds; chlorofluorcarbon (CFC) and hydrochlorofluorcarbon (HCFC) both of which are referred to as ozone-depleting chemicals. Freon manufacture has been discontinued in the United States, and compounds such as R-22, R-11, CFC-114, and CFC-11 are employed as a "transitional" refrigerant.

9.5.3 U.S. Department of Environmental Protection List of Acceptable Substitutes for Chiller Refrigerants

The program SNAP stands for Significant New Alternatives Policy program and is updated each year.

Acceptable Substitutes for CFC-114 and CFC-11 in Chillers and Other Refrigerants

Substitutes are reviewed on the basis of ozone depletion potential, global warming potential, toxicity, flammability, and exposure potential. Lists of acceptable and unacceptable substitutes are updated several times each year. A chronological list of SNAP updates is also available.

Note: SNAP-related information published in the Federal Register takes precedence over all information on this page.

Substitutes for CFC-114 in Centrifugal Chillers

Substitute (Name Used in the Federal Register)	Trade Name	Retrofit/New
HCFC-22		N
HCFC-123		N
HCFC-124		R,N
HFC-134a		N
HFC-227ea		N
HFC-236fa		R,N
Ammonia Vapor Compression		N
Evaporative Cooling		N
Desiccant Cooling		N
Ammonia / Water Absorption		N
Water / Lithium Bromide Absorption		N
HFC-245fa	Genetron® 245fa	R, N

Key: R = Retrofit Uses, N = New Uses

Acceptable Substitutes for CFC-11 in Centrifugal Chillers

Substitutes (Name Used in the Federal Register)	Trade Name	Retrofit/New
HCFC-123		R, N
HCFC-22		N
HFC-134a		N
HFC-227ea		N
HFC-245fa		N
Ammonia Vapor Compression		N
Evaporative Cooling		N
Desiccant Cooling		N
Ammonia / Water Absorption		N
Water / Lithium Bromide Absorption		N

Key: R = Retrofit Uses, N = New Uses

Source: U.S. Department of Environmental Protection.

9.5.3 U.S. Department of Environmental Protection List of Acceptable Substitutes for Chiller Refrigerants (Continued)

Acceptable Substitutes for CFC-12 & R-500 (class I ODS) in Centrifugal Chillers

Substitute (Name Used in the Federal Register)	Trade Name	Refrigerant Being Replaced	Retrofit/ New
HCFC-22		12, 500	N
HCFC-123		12, 500	N
HFC-134a		12, 500	R, N
Ikon A		12	R, N
Ikon B		12	R, N
HFC-227ea		12, 500	N
R-406A	GHG	12, 500	R, N (R-500 only)
Free Zone (HCFC Blend Delta)	Free Zone / RB-276	12, 500	R, N
Freeze 12	Freeze 12	12, 500	R, N
FRIGC FR-12 (HCFC Blend Beta)	FRIGC FR-12	12, 500	R, N
GHG-X4	GHG-X4, Autofrost, Chill-it	12, 500	R, N
GHG-X5	GHG-X5	12, 500	R, N
G2018C	G2018C	12, 500	R, N
Hot Shot	Hot Shot, Kar Kool	12, 500	R, N
HCFC-22/HCFC-142b		12	R, N
R-420A	Choice R-420A	12, 500	R, N
FOR12A	FOR12A	12	R, N
FOR12B	FOR12B	12	R, N
Ammonia Vapor Compression With Secondary Loop		12, 500	N
Evaporative/Desiccant Cooling		12, 500	N
Ammonia / Water Absorption		12, 500	N
Water / Lithium Bromide Absorption		12, 500	N
THR-02	THR-02	12	N
Isceon 39TC	Isceon 39TC	12	R, N

Key: R = Retrofit Uses, N = New Uses

Source: U.S. Department of Environmental Protection.

9.5.3 U.S. Department of Environmental Protection List of Acceptable Substitutes for Chiller Refrigerants (Continued)

Acceptable Substitutes for CFCs (class I ODS) in Reciprocating and Screw Chillers

Substitute (Name Used in the Federal Register)	Trade Name	Refrigerant Being Replaced	Retrofit/ New
HCFC-22		12, 500	N
Ikon B		12	N
THR-02		12	N
HFC-134a		12, 500	R, N
HFC-227ea		12, 500	N
R-401A, R-401B	MP-39, MP-66	12, 500	R, N
R-411A, R-411B		12, 500	R, N
Free Zone (HCFC Blend Delta)	Free Zone / RB-276	12, 500	R, N
Freeze 12	Freeze 12	12, 500	R, N
FRIGC FR-12 (HCFC Blend Beta)	FRIGC FR-12	12, 500	R, N
GHG-X4	GHG-X4, Autofrost, Chill-it	12, 500	R, N
GHG-X5	GHG-X5	12, 500	R, N
G2018C	G2018C	12, 500	R, N
Hot Shot	Hot Shot, Kar Kool	12, 500	R, N
HCFC-22/HCFC-142b		12	R, N
FOR12A	FOR12A	12	R, N
FOR12B	FOR12B	12	R, N
SP34E	SP34E	12	R, N
Evaporative/Desiccant Cooling		12, 500	N
R-407C	Suva 407C, Klea 407C	502	R, N
R-420A	Choice R-420A	12, 500	R, N
R-422C	ICOR XLT1	502	R, N
KDD6	KDD6	12	R, N

Key: R = Retrofit Uses, N = New Uses

Source: U.S. Department of Environmental Protection.

9.5.3 U.S. Department of Environmental Protection List of Acceptable Substitutes for Chiller Refrigerants (Continued)

Acceptable Substitutes for HCFCs (class II ODS) in Centrifugal Chillers

Substitute (Name Used in the Federal Register)	Trade Name	Retrofit/ New
THR-03		N
ISCEON 59, NU-22, R-417	Isceon 59, NU-22	R, N
R-410A, R-410B	AZ-20, Suva 9100, Puron	N
R-407C	Suva 9000, Klea 66	R, N
R-507, R-507A	AZ-50	R, N
Ammonia Vapor Compression With Secondary Loop		N
Ammonia Absorption or Water/Lithium Bromide Absorption		N
Evaporative/Desiccant Cooling		N
R-404A	HP62	R, N
R-125/134a/600a (28.1/70.0/1.9)		R, N
RS-44	RS-44	R, N
R-421A	Choice R421A	R, N
R-422D	ISCEON MO29	R, N
R-424A	RS-44	R, N
KDD5	KDD5	R, N
RS-45 (ASHRAE proposed designation: R-434A)	RS-45	R, N
R-125/290/134a/600a (55.0/1.0/42.5/1.5)	ICOR AT-22	R, N
HFC-245fa	Genetron® 245fa	R, N
R-422B	XAC1, NU-22B	R, N
R-422C	XLT1	R, N

Key: R = Retrofit Uses, N = New Uses

Source: U.S. Department of Environmental Protection.

9.5.3 U.S. Department of Environmental Protection List of Acceptable Substitutes for Chiller Refrigerants (Continued)

Acceptable Substitutes for HCFCs (class II ODS) in Reciprocating and Screw Chillers

Substitute (Name Used in the Federal Register)	Trade Name	Retrofit/ New
THR-03		N
ISCEON 59, NU-22, R-417A	Isceon 59, NU-22	R, N
R-410A, R-410B	AZ-20, Suva 9100, Puron	N
R-407C	Suva 9000, Klea 66	R, N
R-507, R-507A	AZ-50	N
NU-22	NU-22	R, N
Ammonia Vapor Compression With Secondary Loop		N
Ammonia Absorption or Water/Lithium Bromide Absorption		N
Evaporative/Desiccant Cooling		N
R-404A	HP62	R, N
R-125/134a/600a (28.1/70.0/1.9)		R, N
RS-44	RS-44	R, N
R-421A	Choice R421A	R, N
R-422D	ISCEON MO29	R, N
R-424A	RS-44	R, N
KDD5	KDD5	R, N
R-434A	RS-45	R, N
R-125/290/134a/600a (55.0/1.0/42.5/1.5)	ICOR AT-22	R, N
R-422B	XAC1, NU22B	R, N
R-422C	XLT1	R, N
R-427A	Forane 427A	R

Key: R = Retrofit Uses, N = New Uses

Source: U.S. Department of Environmental Protection.

9.6.0 How Chillers Work

A chiller removes heat from a liquid by the use of a compressor or absorption refrigeration cycle.

9.6.1 Vapor Compression Type of Chiller

This type employs a variety of refrigerants and contains four components: a compressor, an evaporator, a condenser, and some type of metering device. There are four basic types of compressors used in vapor-compressor chillers:

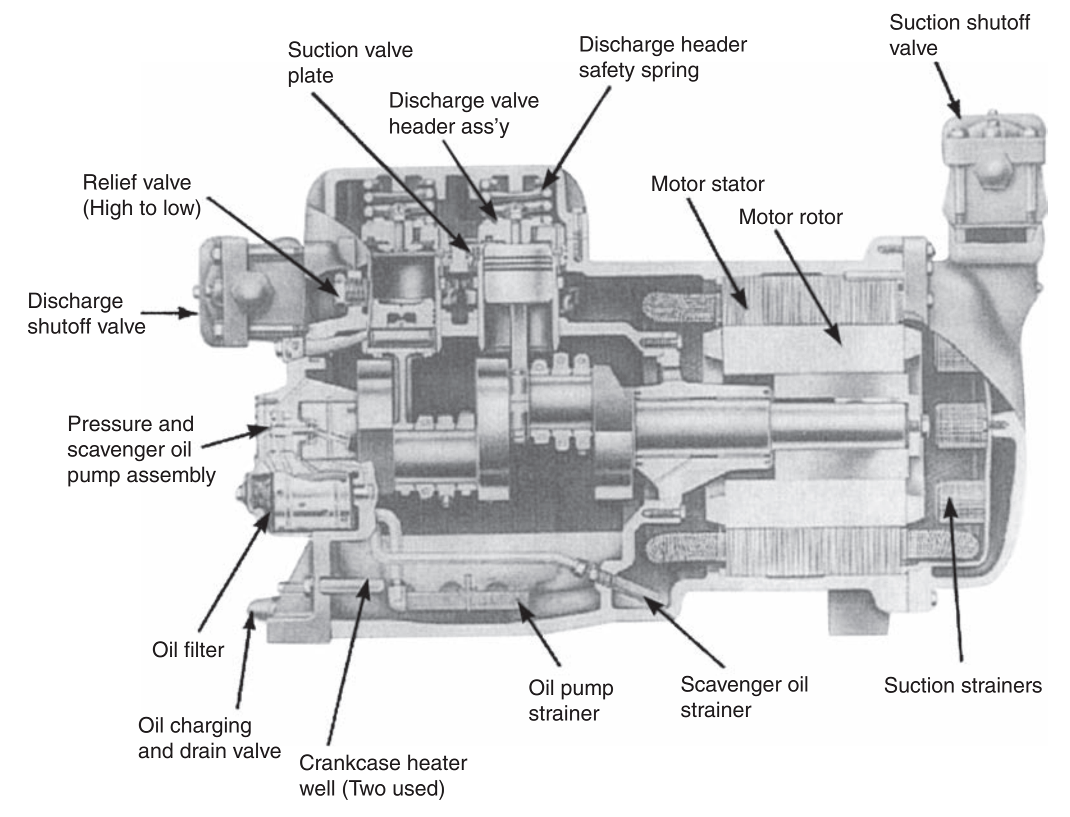
- Reciprocating compressor
- Scroll compressor
- Screw-driven compressor
- Centrifugal compressor

Variable-speed drive (VSD) motors are used on centrifugal, rotary screw, and scroll-type compressors.

9.6.1.1 Reciprocating Compressor

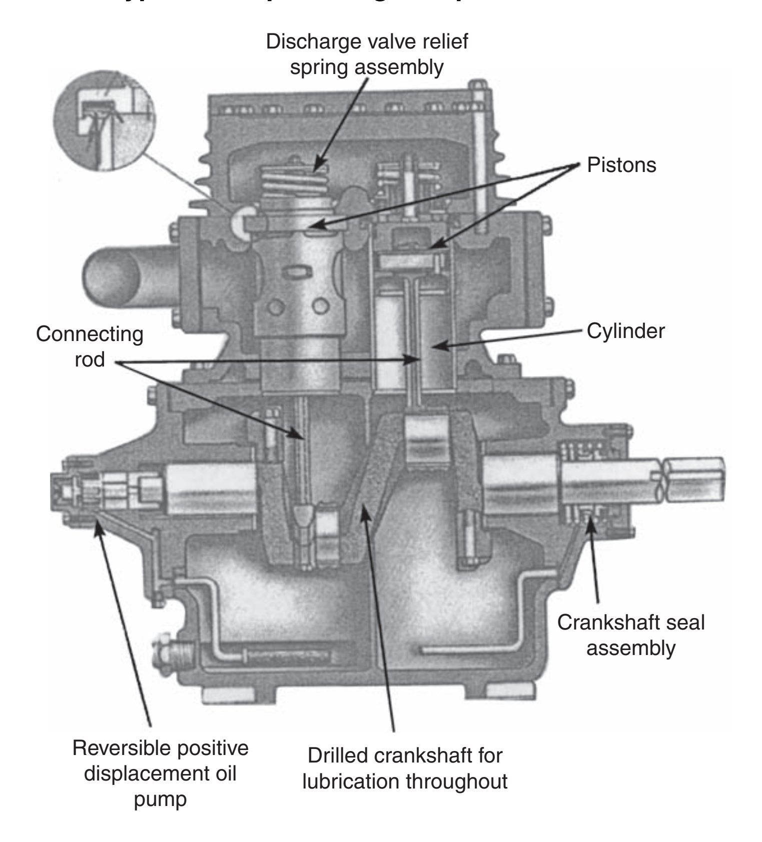
A reciprocating compressor uses the reciprocating action of a piston inside a chamber to compress the refrigerant. The piston moving downward creates a vacuum; because the pressure above the intake valve is greater than the pressure below, refrigerant is sucked into the cylinder in much the same way as in a gasoline engine. When the intake valve closes, the refrigerant is trapped inside the piston and the upward stroke of the piston further compresses the refrigerant. Increased pressure on the exhaust valve forces the refrigerant out of the cylinder so it can be condensed into liquid and absorb heat from the air or water being cooled or chilled.

9.6.1.2 Reciprocating Compressor Schematic



Source: Berg Chilling System, Inc., Toronto, Canada.

9.6.1.3 Another Type of Reciprocating Compressor



Cutaway view of small, external-drive, two-cylinder reciprocating compressor.
The body is a lightweight alloy casting.

Source: Berg Chilling System, Inc., Toronto, Canada.

9.6.1.4 Scroll Compressor

The refrigerant is compressed between two offset spiral disks. Refrigerant is sucked in through inlet ports at the perimeter of the scroll and becomes trapped in the sealed open spaces. As the disk orbits, the volume of the refrigerant is compressed and is discharged through a port at the center of the upper disk. These scroll compressors are quiet and smooth-operating and have the highest efficiency ratio of all compressor types.

9.6.1.5 Hermetic Scroll Compressor and Schematic of Compression Process

Hermetic Scroll Compressors

In recent years, the hermetic single orbiting scroll compressor has become increasingly popular for use in 5-15 ton light commercial and 10-60 ton commercial equipment including both water chillers and direct expansion packaged rooftop air conditioners.

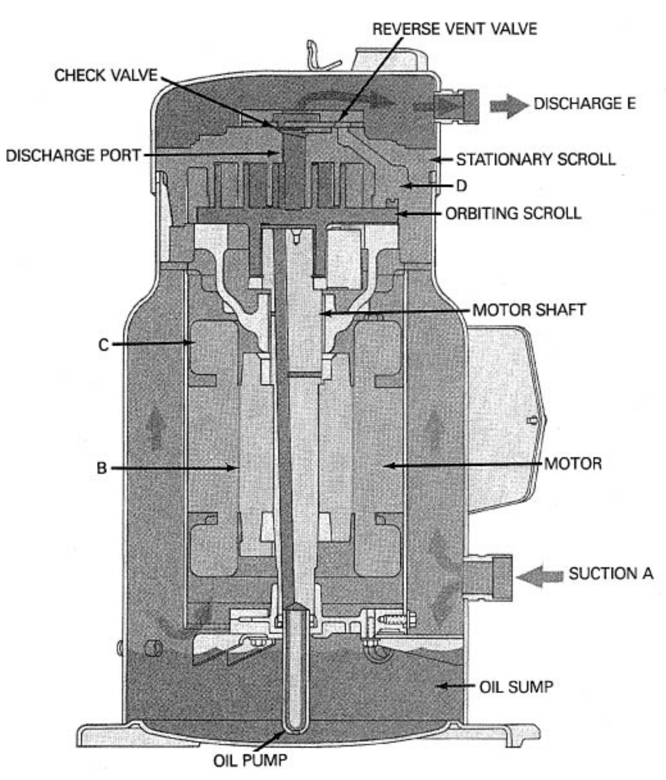


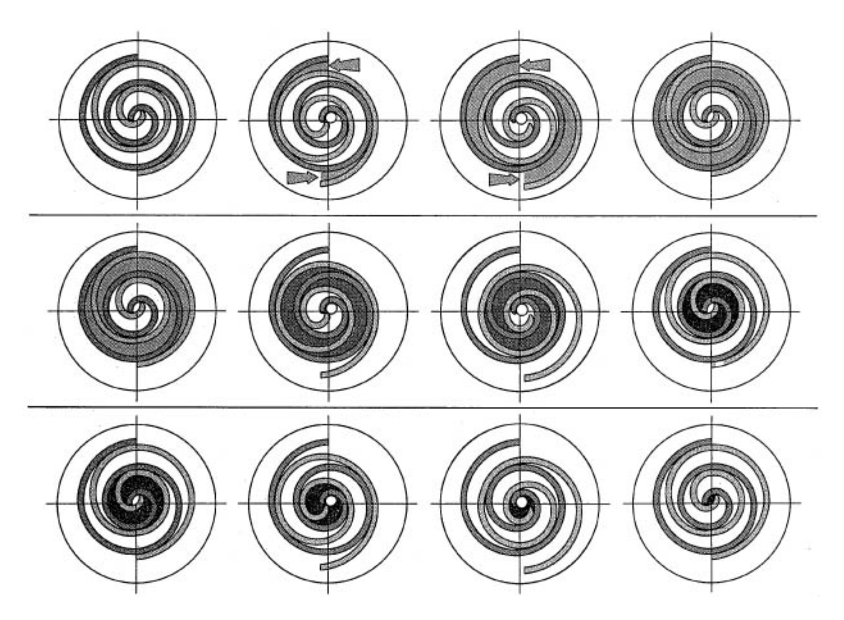
FIGURE 6-O
HERMETIC SCROLL COMPRESSOR

The single orbiting scroll compressor, which uses R-22 refrigerant, is a much simpler design when compared to the reciprocating compressor with about 64 percent fewer parts for the same tonnage compressor. Fewer parts generally means significant reliability and efficiency benefits. As shown in Figure 6-O, the single orbiting scroll eliminates the need for pistons, connecting rods, wrist pins, and valves. Fewer moving parts, less rotating mass, and less internal friction generally means greater efficiency than the comparable tonnage reciprocating compressor. In addition, the scroll design generally allows liquid and dirt to pass through without damaging the compressor.

Figure 6-O is a cutaway view of a hermetic, scroll compressor, showing the relative positions of the principal components. Shown is a Trane 10-ton, 3600 rpm, scroll compressor as an example.

The principle of operation of this example compressor is as follows: The suction gas is drawn into the compressor at A. The gas then passes through the gap between the rotor and stator, B, cooling the motor, before it enters the compressor housing, C. Here, the velocity of the gas is reduced, causing a separation of the entrained oil from the gas stream. The gas then enters the intake chamber, D, that encircles the scrolls.

Finally, the suction gas is drawn into the scroll assembly where it is compressed and discharged into the dome of the compressor. The dome of this example compressor acts as a hot gas muffler which dampens the pulsations before the gas enters the discharge line, E. The Trane scroll compressor has a patented tip seal on the tip of each spiral. The tip seal acts like a piston ring to provide sealing between high and low pressure chambers without wearing the mating surfaces.



By permission, The Trane Company, La Crosse, Wisconsin.

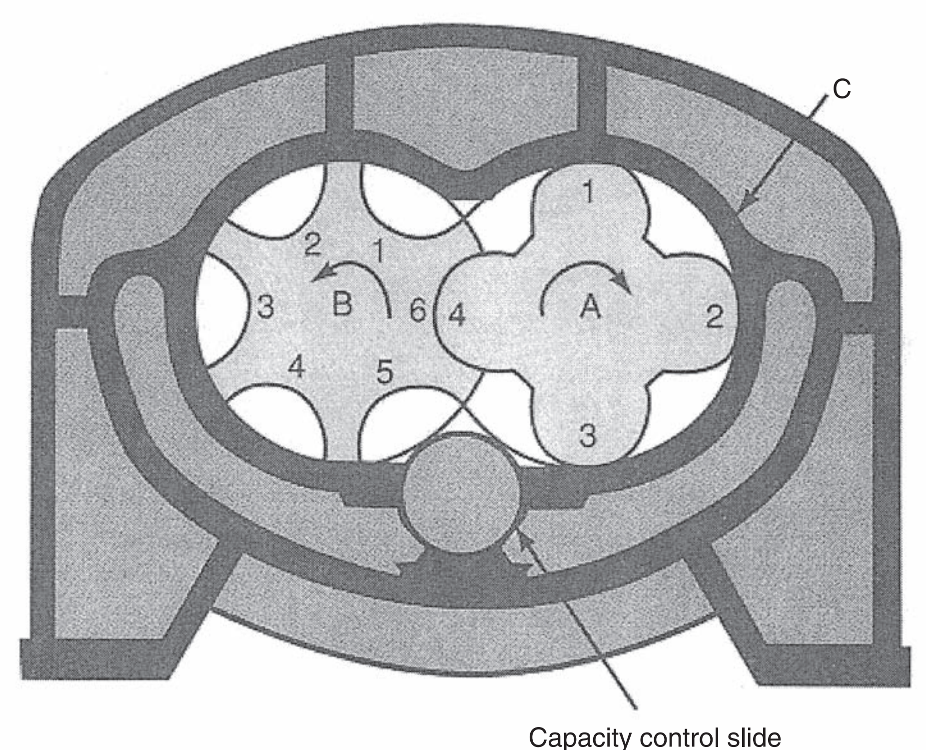
9.6.1.6 Screw-Type Compressors

This type of compressor uses a pair of helical rotors that intermesh as they rotate, alternately exposing and closing off spaces between the ends of the rotors.

9.6.1.7 Cross Section of a Screw Compressor

HELICAL SCREW COMPRESSORS

Screw-type compressors are generally and efficiently used in system with capacity above 20 tons of refrigeration. These compressors use a pair of helical screw rotors, which rotate together inside a chamber and force refrigerant from intake, low side of chamber toward the end high side of



Cross-section of screw compressor. A-Male rotor. B-Female rotor. C-Cylinder.

Source: Berg Chilling System, Inc., Toronto, Canada.

9.6.1.8 Centrifugal or Rotating Compressors

These compressors use the rotating action of an impeller to produce centrifugal force on the refrigerant inside the volute, a round chamber. As the refrigerant is sucked into the chamber, it flows between the impellers, where it is forced outward by centrifugal force, thereby pressurizing the refrigerant. These types of compressors can operate with large volumes of refrigerant at relatively low pressure.

9.6.1.9 Typical Evaporator Piping

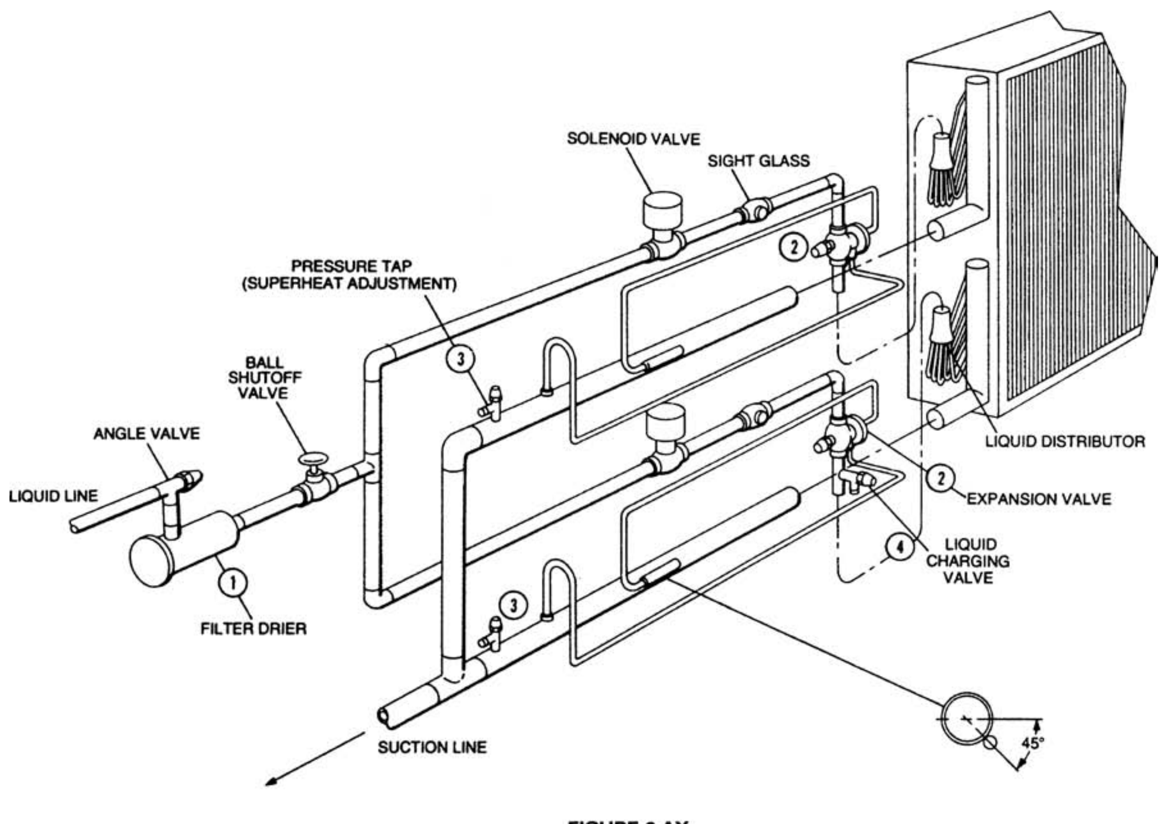
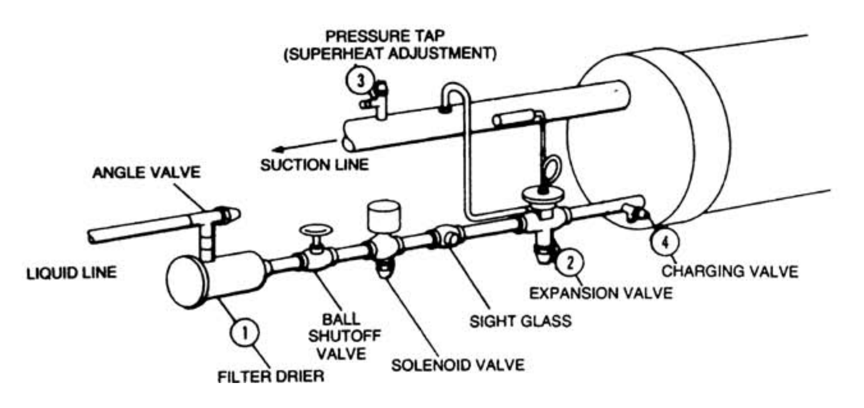
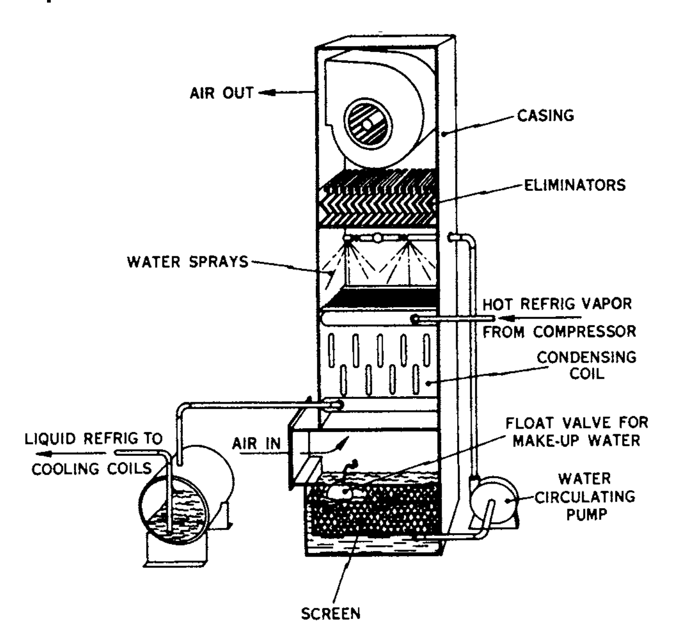


FIGURE 6-AX



By permission, The Trane Company, La Crosse, Wisconsin.

9.6.1.10 Evaporative Condenser



EVAPORATIVE CONDENSER

The evaporative condenser is a form of water-cooled condenser that offers a means of conserving water by combining the condenser and the cooling tower into one piece of equipment.

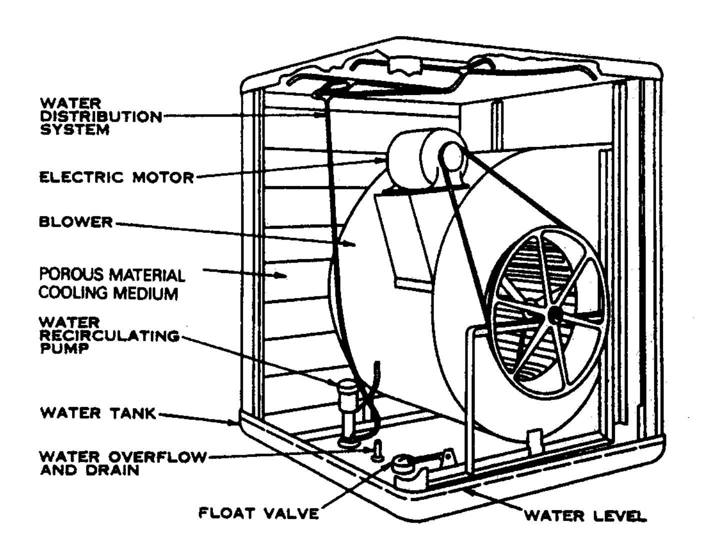
By permission, The Trane Company, La Crosse, Wisconsin.

9.6.1.11 Typical Evaporative Cooler

A typical evaporative cooler is a metal housing with three sides containing porous material kept saturated with water. A pump lifts water from the sump in the bottom of the unit and delivers it to perforated troughs at the top of the unit. The fan draws outside air through the saturated material and discharges it directly into the conditioned space or into a duct system for distribution into several rooms. The porous material is generally spun-glass fibers, aspen excelsior pads, or tinsel made of copper or aluminum. The discharge line from the pump is usually plastic tubing, although copper tubing or iron pipe is sometimes used. A float valve is normally provided to replenish the water evaporated into the air passing throught the unit.

Generally, this valve is set to waste a fixed amount of water at all times. This ensures there is a continual dilution of the natural minerals in the water that are left behind due to evaporation. This is commonly called "blowdown" and provides protection against a sticking float valve.

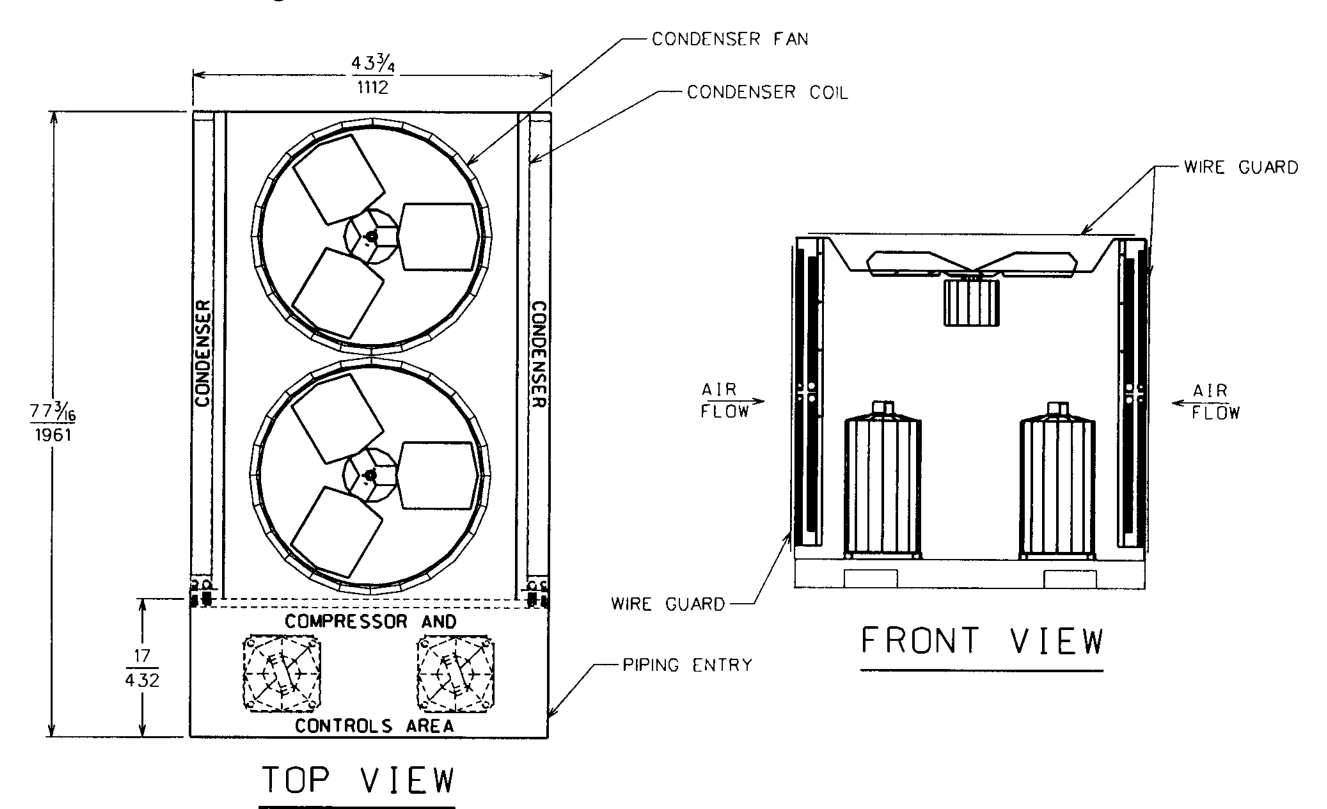
Variations in this design are offered by several manufacturers for applications, primarily in dry climates with a low design wet-bulb temperature.

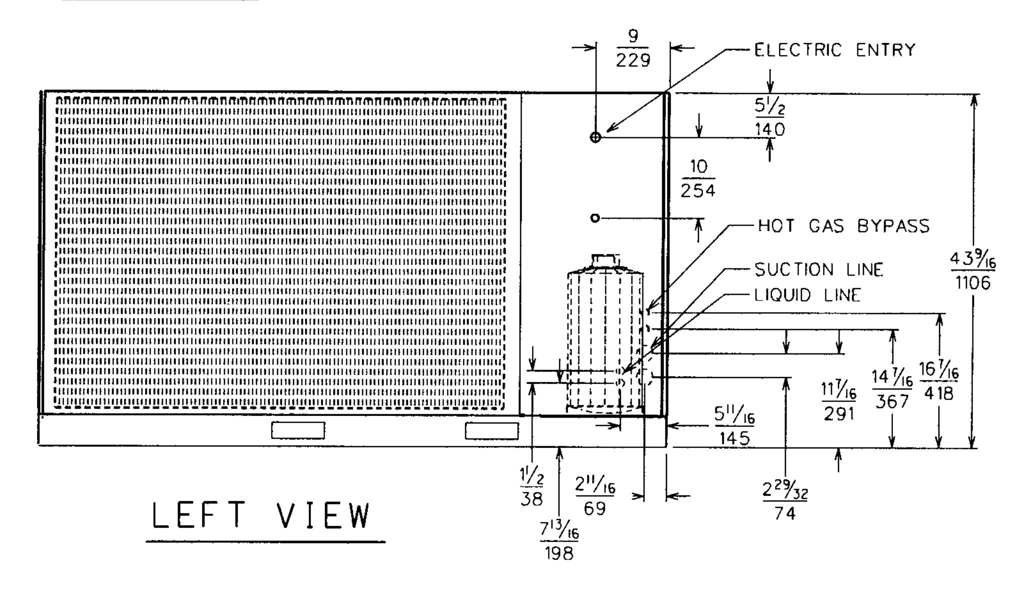


TYPICAL EVAPORATIVE COOLER

By permission, The Trane Company, La Crosse, Wisconsin.

9.6.1.12 Condensing Unit Schematic





9.7.0 Absorption Chiller

The absorption chiller uses water as the refrigerant and achieves refrigeration by relying on the strong affinity between water and a lithium bromide solution. There are five cycles in the operation of an absorption chiller:

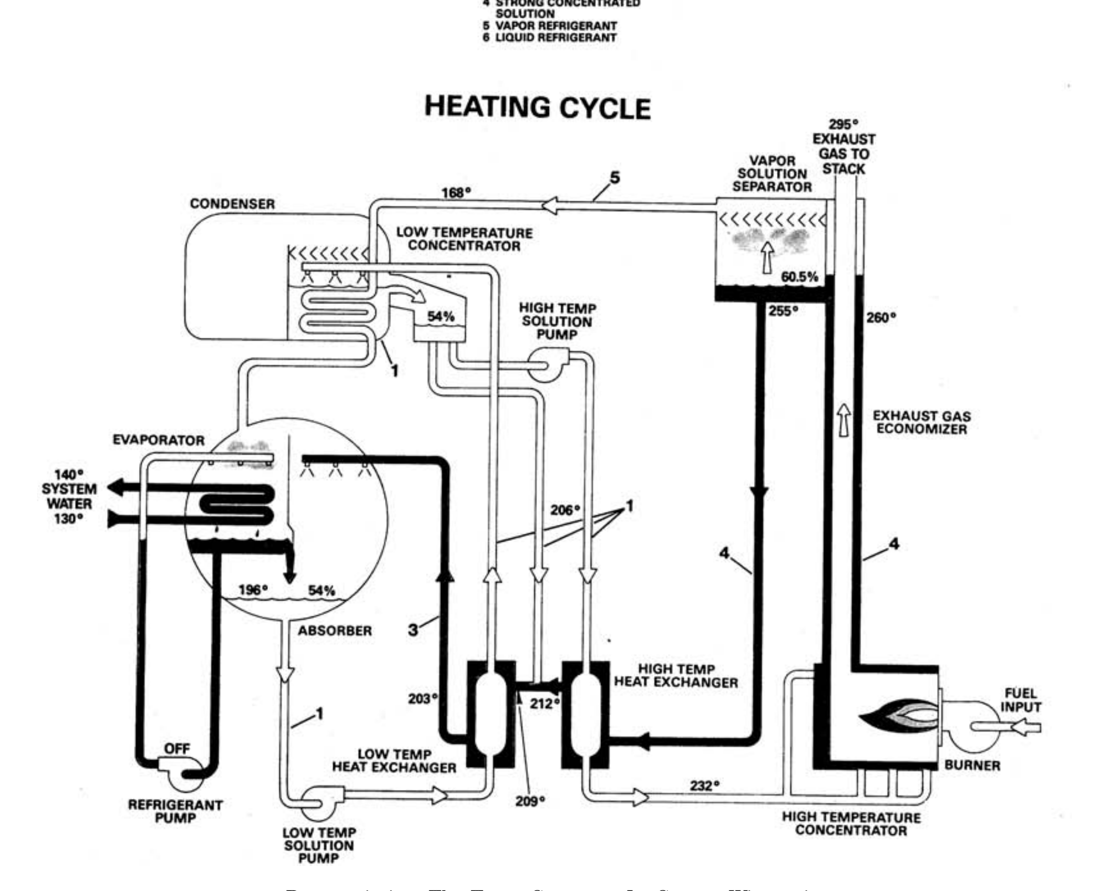
1. A dilute lithium bromide solution is collected in the base of the absorber shell and pumped through a shell and tube heat exchanger for preheating.
2. This dilute solution then moves to the upper shell and surrounds a bundle of tubes carrying steam or hot water. The steam or hot water transfers heat from the dilute bromide solution, and as this bromide solution begins to boil, it sends refrigerant vapor into a condenser, leaving behind the concentrated lithium bromide solution. This solution moves down to the heat exchanger where it is cooled.
3. The refrigerant vapor passes through a mist eliminator to the condenser tube bundle where it condenses on those tubes. The heat is removed by the cooling water moving through the tubes, and as the refrigerant condenses, it moves to a trough at the bottom of the condenser. From there the refrigerant liquid moves to the upper shell in the evaporator where it is sprayed over the evaporator tube bundle.
4. The lower shell of the evaporator works under a vacuum, and the refrigerant liquid boils, creating the refrigerant effect.
5. The refrigerant vapor travels to the absorber, and the strong lithium bromide solution from the generator is sprayed over the top of the absorber tube bundle and pulls the refrigerant vapor into the solution, creating the high vacuum in the evaporator. The heat generated by the absorption of the refrigerant vapor into the lithium bromide solution is removed by the cooling water. The chilling cycle is complete, and the process begins all over again.

9.7.2.1 Direct-Fired Double-Effect Absorption Chiller Schematic

COOLING CYCLE

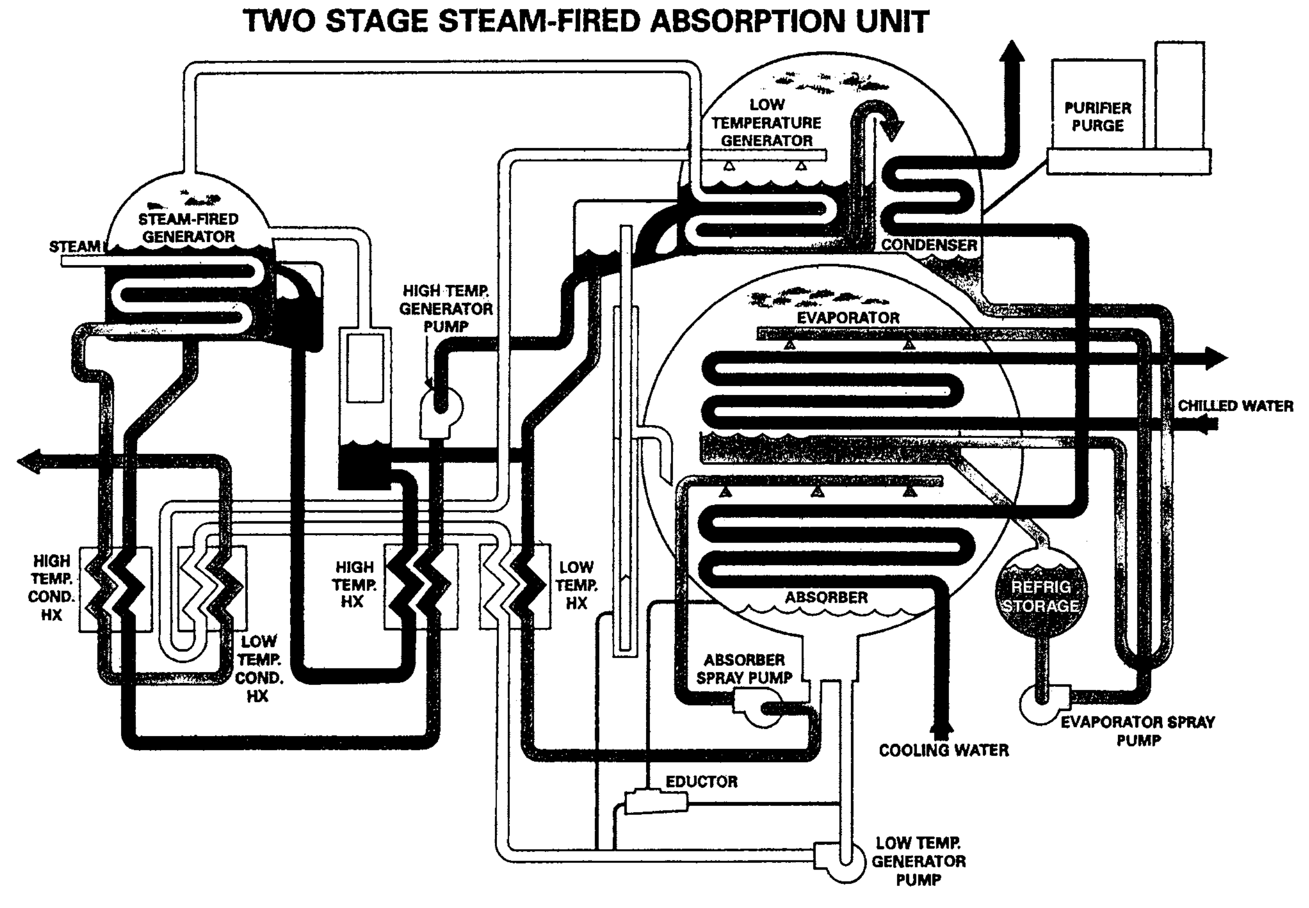
TO COOLING TOWER
95°
CONDENSER
5
300°
FROM COOLING TOWER
VAPOR SOLUTION SEPARATOR
EXHAUST GAS TO STACK
350°
LOW TEMPERATURE CONCENTRATOR
66%
60.3%
180°
HIGH TEMP SOLUTION PUMP
6
195°
97°
2
EXHAUST GAS ECONOMIZER
EVAPORATOR
63.0%
44° SYSTEM WATER 54°
91°
306°
85°
4
4
42°
121°
58.6%
151°
ABSORBER
95°
3
HIGH TEMP HEAT EXCHANGER
1
203°
FUEL INPUT
LOW TEMP HEAT EXCHANGER
192°
BURNER
261°
LIQUID REFRIGERANT PUMP
DILUTE SOLUTION PUMP
HIGH TEMPERATURE CONCENTRATOR

1 DILUTE SOLUTION
2 INTERMEDIATE CONCENTRATED SOLUTION
3 MIXED CONCENTRATED SOLUTION
4 STRONG CONCENTRATED SOLUTION
5 VAPOR REFRIGERANT
6 LIQUID REFRIGERANT



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9.7.2.2 Two-Stage Steam or Hot Water Absorption Cycle



By permission, The Trane Company, La Crosse, Wisconsin.

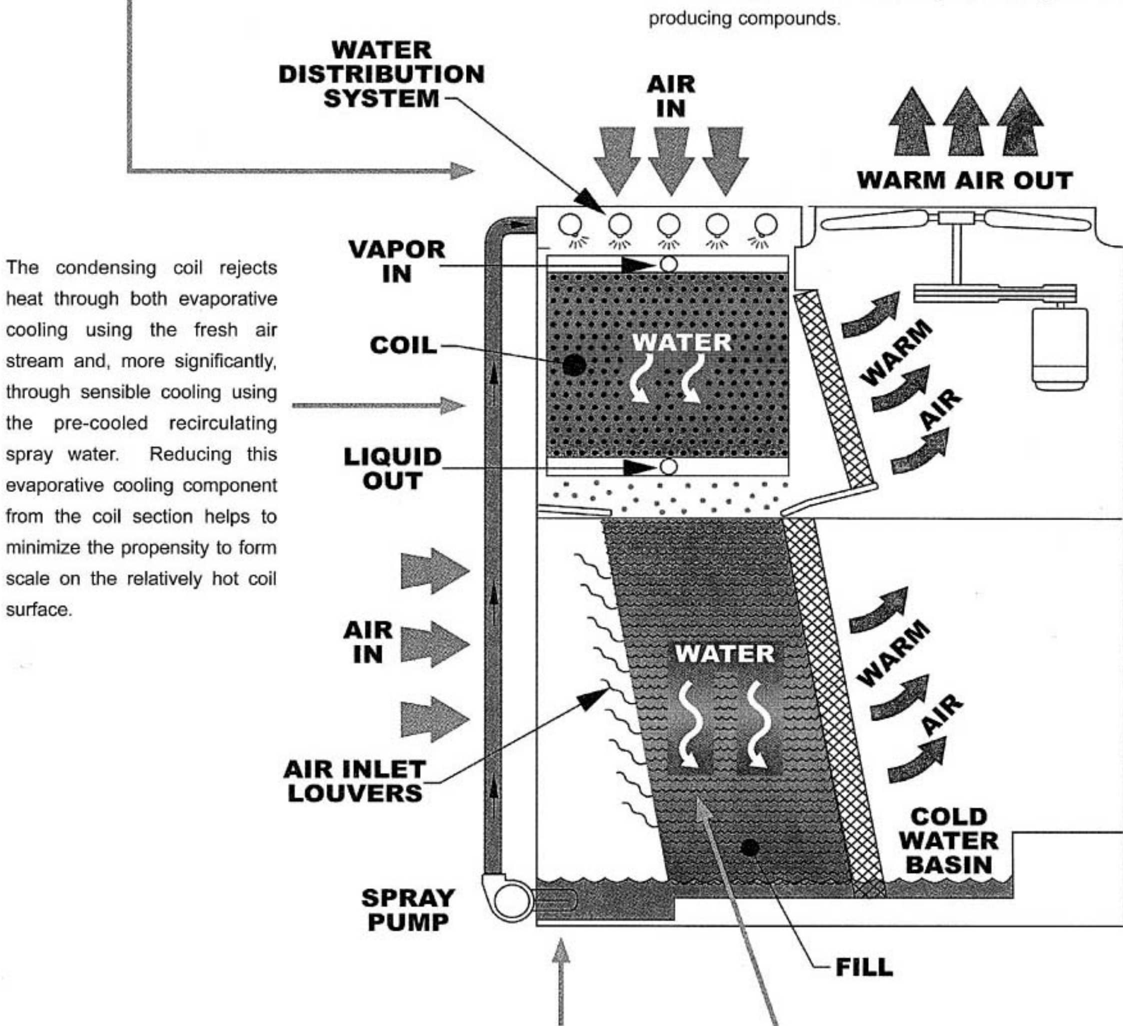
9.8.0 How Cooling Towers Work

1. Cooling tower air blows through a stream of water so that some of the water evaporates.
2. The water trickles through a thick sheet of open mesh.
3. Air blows through the mesh at a 90° angle to the flow of water.
4. The evaporation process cools the stream of water.
5. The cooling tower constantly adds water to replace that lost to evaporation.

9.8.1 Schematic of Cooling Tower Operation

Water is sprayed in parallel with the fresh ambient air flowing over the outside of the condensing coil. Parallel air and water paths minimize scale-producing dry spots that may be found on the bottom of the tubes in other, conventional condensers.

The cooled water increases the temperature differential between the water and the refrigerant, which permits the CXV to deliver a reduced coil size, fewer coil connections, a lower refrigerant charge, and reduced unit weights. This facet further reduces the tendency to form scale on the coil since cooler water offers higher solubility for scale producing compounds.



Water is pumped over the condensing coil at a rate of 10 GPM/ft^2 of coil face area to ensure continuous flooding of the primary heat transfer surface which enhances heat transfer efficiency and minimizes scale formation.

The recirculating spray water falls from the coil to a fill surface section where it is cooled by a second fresh air stream using both evaporative and sensible heat transfer processes.

By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.8.2 Various Types of Cooling Towers and Their Applications

Open Circuit Cooling Towers
Product Lines

	Series 3000	Series 1500	FXT
Principle of Operation			
Configuration	Crossflow	Crossflow	Crossflow
Water distribution	Gravity	Gravity	Gravity
Fan system	Axial fan, induced draft	Axial fan, induced draft	Axial fan, forced draft
Capacity range (Single cell)	220 - 1,350 Nominal Tons 660 - 4,050 GPM at 95°F/85°F/78°F	128 - 428 Nominal Tons 384 - 1,284 GPM at 95°F/85°F/78°F	6 - 268 Nominal Tons 18 - 804 GPM at 95°F/85°F/78°F
Maximum entering water temperature	130°F (54.4°C) Standard Fill; 140°F (60.0°C) with alternative fill material	120°F (48.9°C) Standard Fill; 135°F (57.2°C) with alternative fill material	125°F (51.7°C) Standard Fill; 140°F (60.0°F) with alternative fill material
Typical applications	Medium to large HVAC & industrial applications Replacement of field erected towers w/basinless units	Medium HVAC & industrial applications Counterflow unit replacements Crossflow unit replacements Tight enclosures & installations requiring a single air inlet	Small HVAC & industrial applications

Series 3000 diagram labels: HOT WATER IN; WARM AIR OUT; AIR IN; WATER; WARM AIR; AIR INLET LOUVERS; COLD WATER BASIN; SUMP; FILL; COOLED WATER OUT

Series 1500 diagram labels: WARM AIR OUT; WATER DISTRIBUTION SYSTEM; HOT WATER IN; AIR INLET LOUVERS; WATER; WARM AIR; AIR IN; COLD WATER BASIN; COOLED WATER OUT; FILL

FXT diagram labels: HOT WATER IN; WATER DISTRIBUTION SYSTEM; WATER; AIR OUT; AIR IN; COLD WATER BASIN; FILL; COOLED WATER OUT

By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.8.2 Various Types of Cooling Towers and Their Applications (Continued)

Series V		HXV
VF1	VFL (flow profile)	
Counterflow	Counterflow	Combined Flow
Centrifugal Fan, Forced Draft	Centrifugal Fan, Forced Draft	Axial Fan, Induced Draft
4.1 - 543 Nominal Tons 12.4 - 1,629 GPM 95˚F/85˚F/78˚F	3.9 - 108 Nominal Tons 11.6 - 324.6 GPM at 95˚F/85˚F/78˚F	160 - 305 Nominal tons 480 - 915 GPM at 95˚F/85˚F/78˚F
180˚F (82.2˚C)	180˚F (82.2˚C)	Entering water temperature can exceed 180˚F but is application specific; contact your local BAC Representative for details.
Small to medium HVAC & industrial applications such as water source heat pump loops and air compressor cooling Indoor installations High temperature applications Tight enclosures & installations requiring a single air inlet Extremely sound sensitive applications	Small to medium HVAC & industrial applications Installations with extremely low height requirements Indoor installations High temperature industrial applications Extremely sound sensitive applications	Small to medium HVAC & industrial applications such as water source heat pump loops and air compressor cooling Installations requiring plume abatement Installations requiring water conservation Large range/close approach applications High temperature industrial applications

By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.8.3 Open-Circuit Cooling Towers—Principle of Operation and Configuration

Open Cooling Towers

Open cooling towers provide evaporative cooling for many types of systems. The specific application will largely determine which BAC Cooling Tower is best suited for a project. The table on pages D5 and D6 is intended as a general guide. Specific application assistance is available through your local BAC Representative.

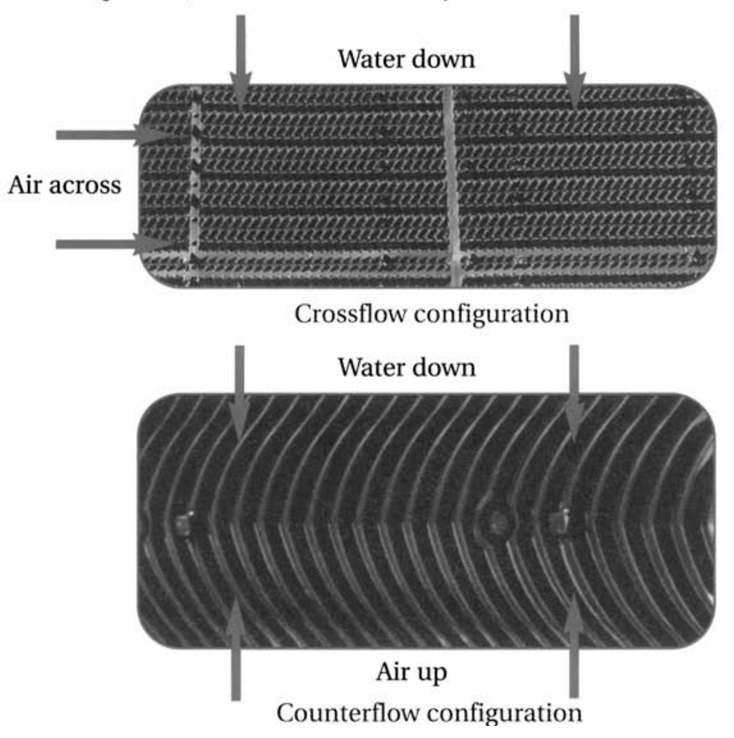
Principle of Operation

Open cooling towers reject heat from water-cooled systems to the atmosphere. Hot water from the system enters the cooling tower and is distributed over the fill (heat transfer surface). Air is induced or forced through the fill, causing a small portion of the water to evaporate. This evaporation removes heat from the remaining water, which is collected in the cold water basin and returned to the system to absorb more heat.

Each open cooling tower line, although operating under the same basic principle of operation, is arranged a little differently. See the schematics on pages D5 and D6 for product specific details.

Configuration

There are two main configurations of factory assembled open cooling towers: crossflow and counterflow. In crossflow cooling towers, the water flows vertically down the fill as air flows horizontally across.
In counterflow cooling towers, the water flows vertically down the fill as air flows vertically up.



By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.8.4 Advantages of Closed-Circuit Cooling Towers

Open cooling towers expose process cooling water to the atmosphere, typically as part of a chiller system loop (see Figure 1). Open towers use an efficient, simple, and economical design. All components in an open system must be compatible with the oxygen introduced via the cooling tower.

Closed circuit cooling towers completely isolate process cooling fluid from the atmosphere. This is accomplished by combining heat rejection equipment with a heat exchanger in a closed circuit tower (see Figure 2). A closed loop system protects the quality of the process fluid, reduces system maintenance, and provides operational flexibility at a slightly higher initial cost.

When deciding which system is best for an application, several factors should be considered.

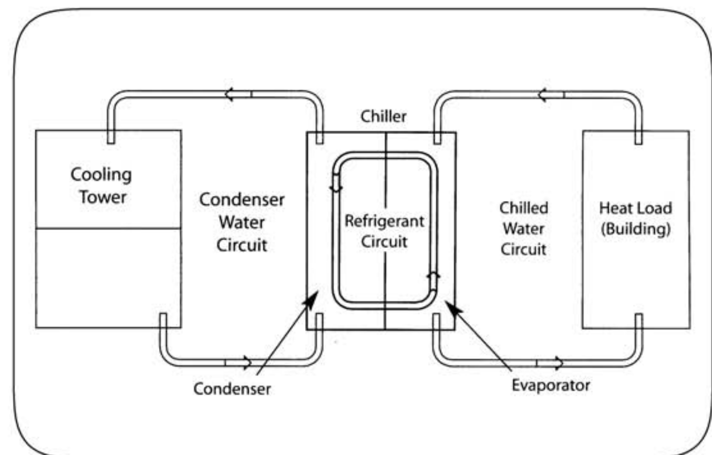
Performance

If an application must produce full capacity throughout the year, maintaining a clean, reliable system loop is critical. Isolating the process fluid in a closed loop system prevents airborne contaminants from entering and fouling the system. Sustaining optimum performance in an open loop system will require regular maintenance to assure similar efficiency. High efficiency chillers and heat exchangers rely on clean process water to function properly and are significantly impacted by even small amounts of fouling.

Expense

The initial equipment cost of an open loop system will be less than a comparably sized closed loop system, since the open system does not include the intermediate heat exchanger component. However, the higher first cost of a closed loop system will be paid back during years of operation through the following savings:

- Cleaner process fluid results in a cleaner internal surface area, and higher efficiency components in the system (e.g. chiller)
- Reduced system maintenance costs
- Reduced water treatment costs for evaporative equipment
- Operating in 'free cooling' mode during the winter to save energy consumption



By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.8.5 Evaporative Condenser System with a Closed-Circuit Cooling Tower

Closed Circuit Fluid Cooling

To eliminate the problem of system contamination associated with using spray water for auxiliary cooling, BAC recommends that a closed system be used for that cooling whenever possible. A separate closed circuit cooling tower, or a split circuit coil in the evaporative condenser, with one circuit for condensing the refrigerant and the other for cooling the liquid, are two good solutions.

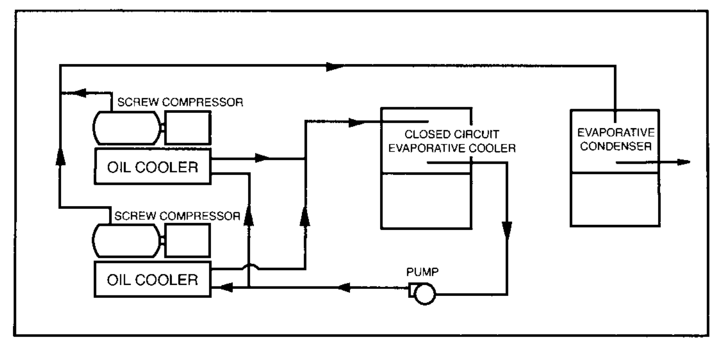


Figure 14 — Evaporative condenser with closed circuit cooling tower for fluid cooling: cooling oil coolers for refrigeration screw compressors

As an example, a closed circuit cooling tower could be used to cool water or glycol solution for oil coolers of refrigeration screw compressors. Figure 14 shows a typical arrangement. This is the ideal cooling system because it provides the following important advantages:

1. Provides closed loop cooling, which precludes the contamination of system fluid.
2. Provides independent control of the condensing and water-cooling systems by separating these two functions into two or more units.
3. Permits the evaporative condenser to be operated as an air-cooled condenser in cold weather, thus minimizing freeze up problems.

By permission, Baltimore Aircoil (BAC), Baltimore, MD.

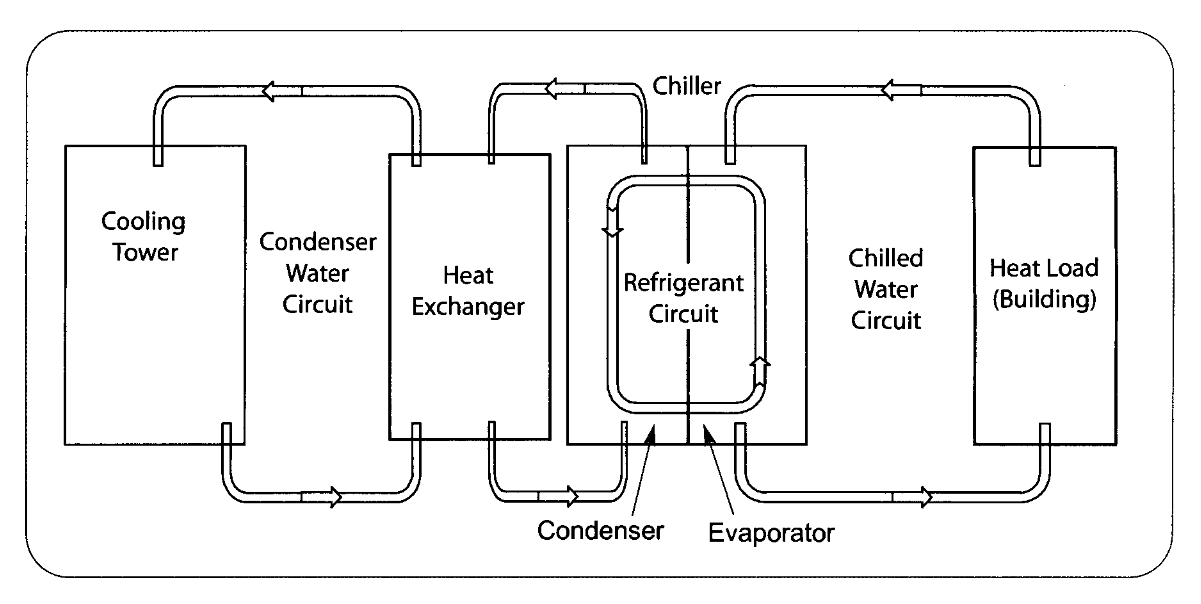
9.8.6 Chiller Loop with an Open Tower/Heat Exchanger Combination

Closed Circuit Tower vs. Open Tower / Heat Exchanger

Sometimes, an open cooling tower is paired with a heat exchanger (see Figure 3) to capture some of the benefits of closed loop cooling. Choosing closed circuit cooling towers over this open tower/heat exchanger combination may still be a better choice for the following reasons:

- Total cost: Addition of a heat exchanger (pump, piping, etc.) to the open tower loop brings the initial cost much closer to that of the closed circuit tower system
- Single piece of equipment: Compact design of the closed circuit tower conserves space in a self-contained package, compared to multiple locations for the tower/heat exchanger arrangement
- Maintenance: Narrow spacing in heat exchanger (e.g. plate and frame) may trap solids introduced by the open tower, requiring frequent, time consuming cleaning to assure optimum performance
- Dry operation: Open tower/heat exchanger system cannot be run dry in the winter

These guidelines provide some general information to help decide whether a closed circuit cooling tower is better suited for a particular application than an open tower, with or without a heat exchanger. For additional assistance with a project, please contact your local BAC Representative.



By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.8.7 Quick Reference Checklist for Cooling Towers

QUICK REFERENCE

Maintenance Check List



Type of Service:	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
1. Check fan bearings and lubricate, if necessary.												
2. Check tightness and adjustment of thrust collars on sleeve bearing units and locking collars on ball bearing units.												
3. Check belt tension and adjust if necessary. For gear drive units, check oil level.												
4. Clean strainer (if atmosphere is extremely dirty, it may be necessary to clean strainer weekly).												
5. Check for biological growth in basin. Consult water treatment specialist if such growth is not under control.												
6. Clean and flush basin.												
7. Check spray distribution system. Check spray branches and clean as necessary. Check and re-position nozzles, if necessary.												
8. Check operating water level in the basin and adjust float valve, if required.												
9. Check bleed rate and adjust if necessary.												
10. Check fans and air inlet screens and remove any dirt or debris.												

Once a Year: Inspect and clean protective finish inside and out. Look particularly for any signs of spot corrosion. Clean and refinish any damaged protective coating.

Before undertaking start-up procedures or performing inspection or maintenance of BAC equipment, make certain the power has been disconnected. Refer to appropriate operating and maintenance manuals and comply with all caution label instructions.

By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.9.0 Basic Ice Storage System Schematic

Suitable For: Industrial Refrigeration • Process Cooling • Batch Cooling

Principle of Operation

The basic ice storage system includes an ICE CHILLER® Thermal Storage Unit, a refrigeration system, and ice water pump as shown below in Figure 1.

When no cooling load exists, the refrigeration system operates to build ice on the outside surface of the coil. This refrigeration effect is provided by feeding refrigerant directly into the coil. To increase the heat transfer during the ice build cycle the water is agitated by air bubbles from a low pressure distribution system beneath the coil. When the ice has reached design thickness, BAC's exclusive ICE-LOGIC™ Ice Thickness Controller sends a signal to turn off the refrigeration system.

When chilled water is required for cooling, the ice water pump is started, and the meltout cycle begins. Warm water returning from the load circulates through the ICE CHILLER® Thermal Storage Unit and is cooled by direct contact with the melting ice. During this cycle, the tank water is also agitated to provide more uniform ice melting and a constant supply water temperature of 36°F or less.

For a closed chilled water loop, see Figure 2. With this system, warm return water from the load is pumped through a heat exchanger and cooled by the ice water circuit from the ICE CHILLER® Thermal Storage Unit.

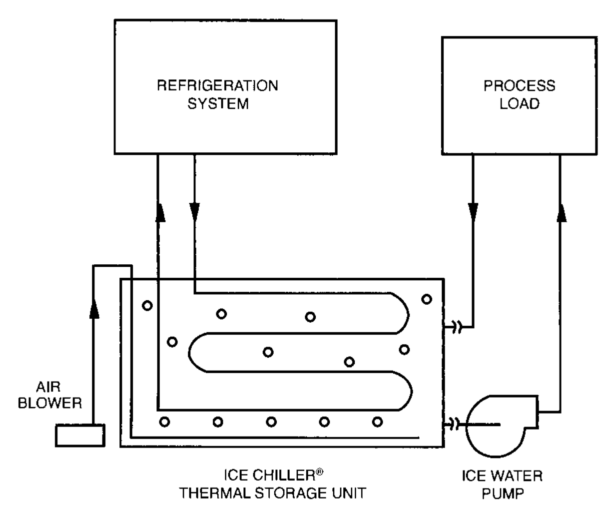


Figure 1

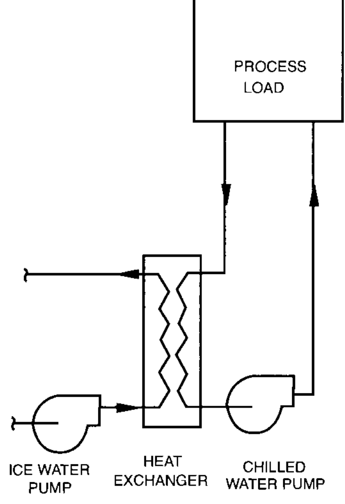


Figure 2

By permission, Baltimore Aircoil (BAC), Baltimore, MD.

9.10.0 Heat Exchangers

A heat exchanger is a piece of equipment that efficiently transfers heat from one medium to another. A familiar example of a heat exchanger is an automobile radiator in which hot engine fluid is distributed through the radiator and air flowing through that device transfers heat from the engine fluid to the atmosphere. In a heat exchanger design, both convection and conduction principles of heat transfer are used.

Heat exchangers are classified according to their flow arrangements:

- *Parallel flow*. Two fluids enter the exchanger at the same end and travel parallel to each other.
- *Counterflow*. Fluids enter the exchanger from opposite ends. This is the most efficient type of heat exchanger.
- *Cross-flow.* Fluids enter and travel perpendicular to each other.

Heat exchangers are designed to maximize the surface area of the wall between the two fluids and also minimize resistance to fluid flow which could possibly affect maximum heat transfer.

9.10.1 Shell and Tube Heat Exchangers

This type of heat exchanger is the most common and consists of a shell (a pressure vessel) and a bundle of tubes inside. One fluid travels through the tubes, another fluid flows over the tubes within the shell, and the transfer of heat takes place between the two fluids. The tube bundle within the shell can be plain surfaced, finned, or corrugated.

9.10.2 Plate-Type Heat Exchangers

In this type of heat exchanger, a series of thin, slightly separated plates with large surface areas allow fluid flow over the surfaces to transfer heat some one medium to another. When used in HVAC applications, these plate and frame type of exchangers are gasketed so that they can be disassembled for periodic maintenance and cleaning. Permanently bonded plate heat exchangers are typically used in closed-loop refrigeration applications.

9.10.3 Plate Fin Type of Heat Exchanger

This type of heat exchanger uses finned passages to increase the effectiveness of the heat transfer. The straight, offset, or wavy fins are used in both cross-flow and counterflow applications.

9.10.4 Regenerative Heat Exchangers

In this type of heat exchanger, both hot and cold liquids occupy the same space, and the matrix of materials acts as a sink or a source of heat flow.

9.10.5 Evaporative-Type Heat Exchangers

In this type of heat exchanger, the fluid is evaporatively cooled in the same space as the coolant, similar to the process that takes place in a cooling tower.

9.10.6 Phase-Change Heat Exchangers

These heat exchangers contain a material that has a change of phase, such as changing from a solid to a liquid phase. For example, power plants use heat exchangers to boil water into steam.

9.10.7 HVAC Heat Exchangers

When liquid is employed in HVAC heat exchangers, water or a water-glycol solution or a refrigerant is used. For heating coils, hot water and steam are the most common media; and for cooling coils, chilled water and refrigerant are the staples. When a refrigerant is used, the coiling coil is the evaporator.

9.11.0 Heat Pumps

A heat pump is a mechanical device that moves air. In winter it moves air from the outside, draws heat from it, and transfers that heat inside. In the summer, the heat pump reverses this process and draws heat from the inside and dumps it outside.

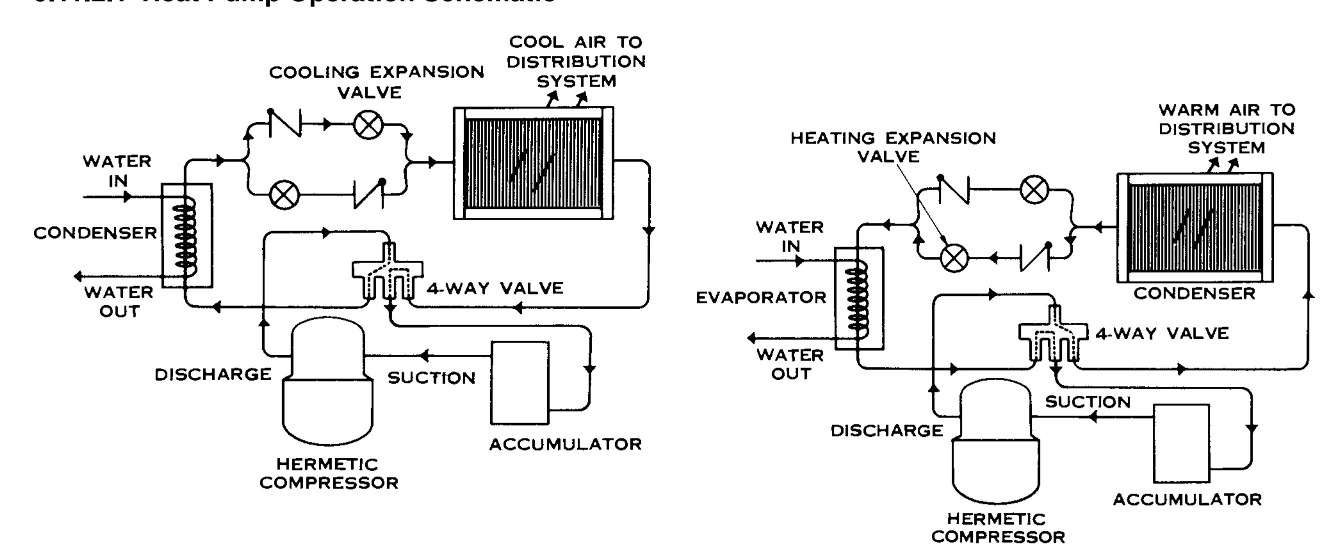
9.11.1 Heat Pump as a Heater

All air has a temperature except absolute zero (–460°F), and a heat pump absorbs that heat from the outside, transferring it to the interior. It does so via a refrigerant in a coil. The absorption of heat changes the refrigerant from a low-temperature liquid to a low-pressure vapor which then passes through a compressor where it is compressed into a high-pressure, high-temperature vapor. This hot vapor circulates into a coil where the coil absorbs the heat, distributing it inside the building or structure.

9.11.2 Heat Pump as an Air Conditioner

The indoor coil of the unit contains a cold liquid refrigerant, and as the indoor air passes through this coil, the refrigerant-cooled coil absorbs heat from the indoor air. The absorption of heat by the refrigerant turns the refrigerant from a liquid to a vapor, and a compressor pumps the heat-laden vapor through a line to an outside coil, where the heat is dissipated. As the heat is dissipated, the refrigerant vapor is cooled and changes back to a liquid which is then pumped back to the interior, where the cycle is repeated.

9.11.2.1 Heat Pump Operation Schematic



WATER TO AIR HEAT PUMP CYCLES

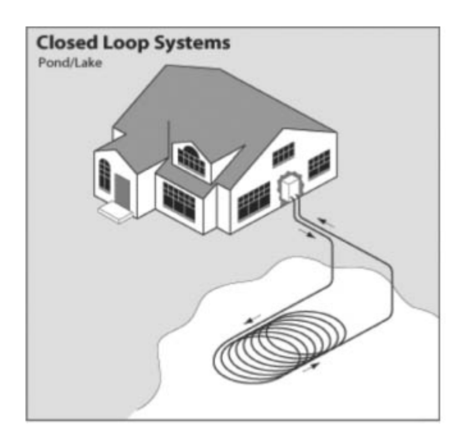
(a) HEAT PUMP WITH VARIABLE REFRIGERANT CIRCUIT — COOLING CYCLE

(b) HEAT PUMP WITH VARIABLE REFRIGERANT CIRCUIT — HEATING CYCLE

By permission, The Trane Company, La Crosse, Wisconsin.

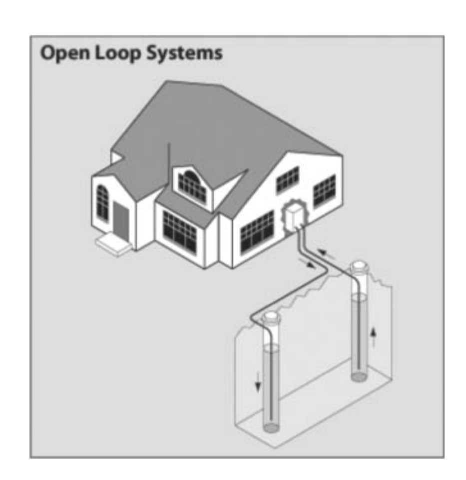
9.11.3 Geothermal Heat Pump Systems

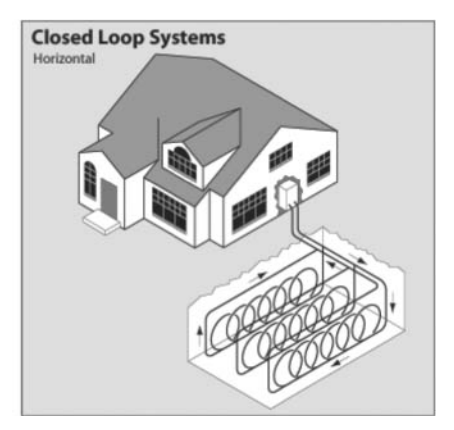
Below is a U.S. Department of Energy presentation of geothermal heat pump applications for residential construction.



Open-Loop System

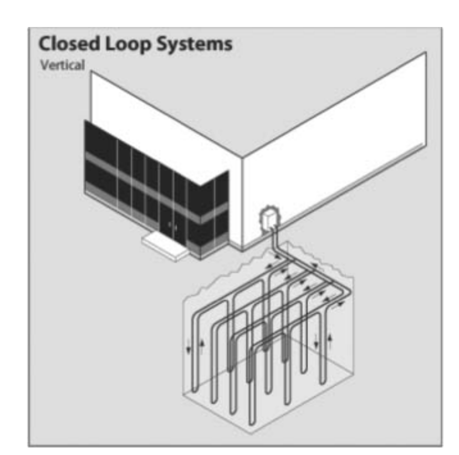
This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the GHP system. Once it has circulated through the system, the water returns to the ground through the well, are charge well, or surface discharge. This option is obviously practical only where there is an adequate supply of relatively clean water, and all local codes and regulations regarding groundwater discharge are met.





Vertical

Large commercial buildings and schools often use vertical systems because the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching, and they minimize the disturbance to existing landscaping.



Pond/Lake

If the site has an adequate water body, this may be the lowest cost option. A supply line pipe is run underground from the building to the water and coiled into circles at least eight feet under the surface to prevent freezing. The coils should only be placed in a water source that meets minimum volume, depth, and quality criteria.

Source: U.S. Department of Energy.

9.11.4 Heat Pump Efficiency Ratings

- *SEER (seasonal energy efficiency ratio).* The SEER indicates how efficiently the unit utilizes electricity—the higher the rating, the less electricity it requires to cool a certain area.
- *HSPF (heating seasonal performance factor).* The HSPF identifies the efficiency of the heat pump; the higher the rating, the less electricity it requires to heat a certain area.

9.12.0 Glossary of HVAC Terms

Air Change per Hour (ACH)
: The number of times per hour that the volume of a specific room or building is supplied or removed from that space by mechanical and natural ventilation.

Air handler, or **air handling unit** (AHU)
: Central unit consisting of a blower, heating and cooling elements, filter racks or chamber, dampers, humidifier, and other central equipment in direct contact with the airflow. This does not include the ductwork through the building.

British thermal unit (BTU)
: Any of several units of energy (heat) in the HVAC industry, each slightly more than 1 kJ. One BTU is the energy required to raise one pound of water one degree Fahrenheit, but the many different types of BTU are based on different interpretations of this "definition". In the United States the power of HVAC systems (the rate of cooling and dehumidifying or heating) is sometimes expressed in BTU/hour instead of watts.

Chiller
: A device that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This cooled liquid flows through pipes in a building and passes through coils in air handlers, fan-coil units, or other systems, cooling and usually dehumidifying the air in the building. Chillers are of two types; air-cooled or water-cooled. Air-cooled chillers are usually outside and consist of condenser coils cooled by fan-driven air. Water-cooled chillers are usually inside a building, and heat from these chillers is carried by recirculating water to outdoor cooling towers.

Coil
: Equipment that performs heat transfer when mounted inside an Air Handling unit or ductwork. It is heated or cooled by electrical means or by circulating liquid or steam within it. Air flowing across it is heated or cooled.

Condenser
: A component in the basic refrigeration cycle that ejects or removes heat from the system. The condenser is the hot side of an air conditioner or heat pump. Condensers are heat exchangers, and can transfer heat to air or to an intermediate fluid (such as water or an aqueous solution of ethylene glycol) to carry heat to a distant sink, such as ground (earth sink), a body of water, or air (as with cooling towers).

Constant air volume (CAV)
: A system designed to provide a constant air volume per unit time. This term is applied to HVAC systems that have variable supply-air temperature but constant air flow rates. Most residential forced-air systems are small CAV systems with on/off control.

Controller
: A device that controls the operation of part or all of a system. It may simply turn a device on and off, or it may more subtly modulate burners, compressors, pumps, valves, fans, dampers, and the like. Most controllers are automatic but have user input such as temperature set points, e.g. a thermostat. Controls may be analog, or digital, or pneumatic, or a combination of these.

Damper
: A plate or gate placed in a duct to control air flow by introducing a constriction in the duct.

Deep lake water cooling
: The heat is rejected to deep lake regions to cool homes and offices, reducing the energy costs.

ΔT
: ΔT (delta T) is a reference to a temperature difference. It is used to describe the difference in temperature of a heating or cooling fluid as it enters and as it leaves a heat transfer device. This term is used in the calculation of coil efficiency.

Evaporator
: A component in the basic refrigeration cycle that absorbs or adds heat to the system. Evaporators can be used to absorb heat from air (by reducing temperature and by removing water) or from a liquid. The evaporator is the cold side of an air conditioner or heat pump.

Fan coil unit (FCU)
: A small terminal unit that is often composed of only a blower and a heating and/or cooling coil (heat exchanger), as is often used in hotels, condominiums, or apartments. One type of fan coil unit is a unit ventilator.

Fresh air intake (FAI)
: An opening through which outside air is drawn into the building. This may be to replace air in the building that has been exhausted by the ventilation system, or to provide fresh air for combustion of fuel.

Furnace
: A component of an HVAC system that adds heat to air or an intermediate fluid by burning fuel (natural gas, oil, propane, butane, or other flammable substances) in a heat exchanger.

Grille
: A facing across a duct opening, usually rectangular is shape, containing multiple parallel slots through which air may be delivered or withdrawn from a ventilated space.

Source: Wikipedia.

9.12.0 Glossary of HVAC Terms (Continued)

Heat load, **heat loss**, or **heat gain**
Terms for the amount of heating (heat loss) or cooling (heat gain) needed to maintain desired temperatures and humidities in controlled air. Regardless of how well-insulated and sealed a building is, buildings gain heat from warm air or sunlight or lose heat to cold air and by radiation. Engineers use a heat load calculation to determine the HVAC needs of the space being cooled or heated.

Louvers
Blades, sometimes adjustable, placed in ducts or duct entries to control the volume of air flow. The term may also refer to blades in a rectangular frame placed in doors or walls to permit the movement of air.

Makeup air unit (MAU)
An air handler that conditions 100% outside air. MAUs are typically used in industrial or commercial settings, or in "once-through" (blower sections that only blow air one-way into the building), "low flow" (air handling systems that blow air at a low flow rate), or "primary-secondary" (air handling systems that have an air handler or rooftop unit connected to an add-on makeup unit or hood) commercial HVAC systems.

Packaged terminal air conditioner (PTAC)
An air conditioner and heater combined into a single, electrically-powered unit, typically installed through a wall and often found in hotels.

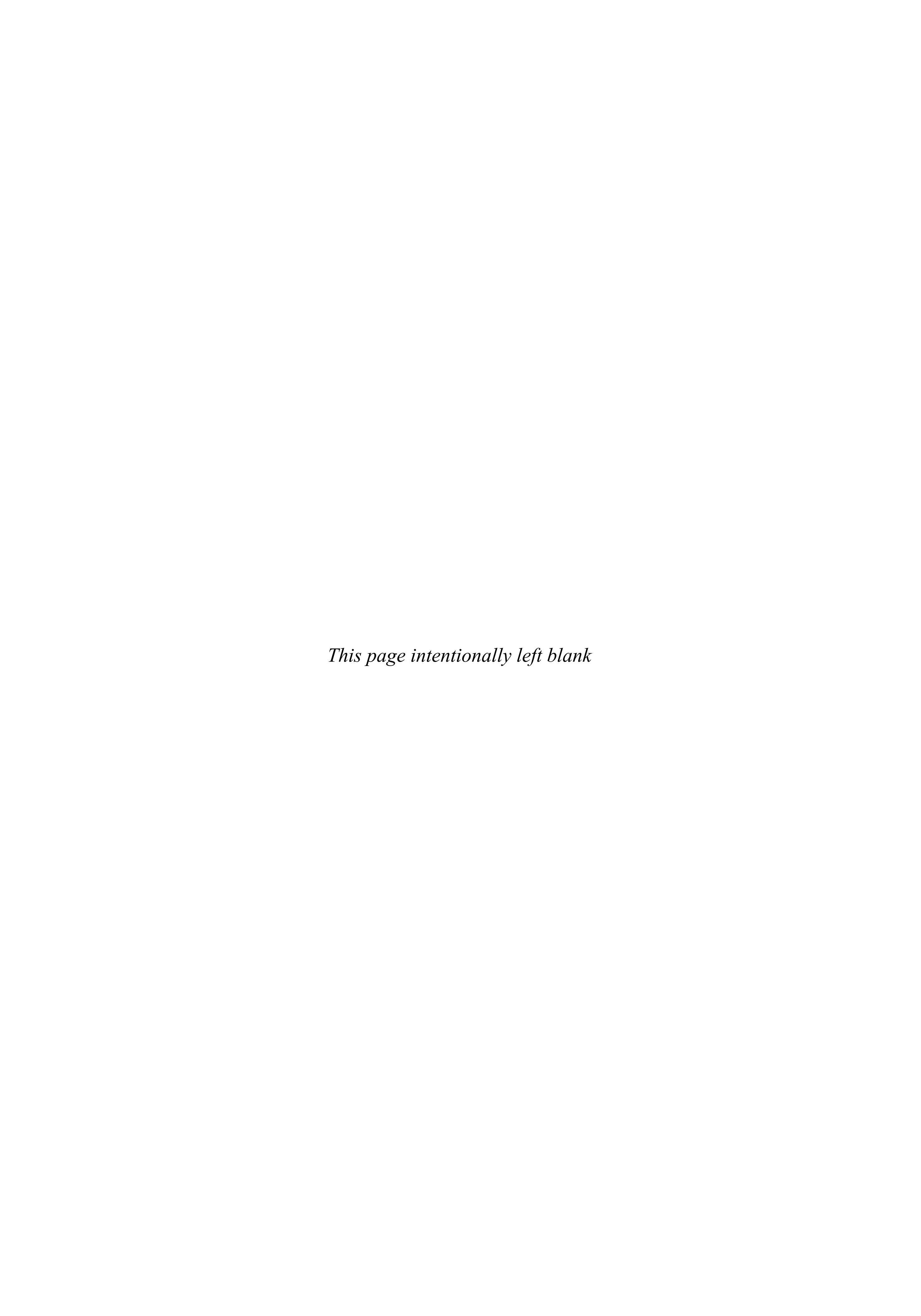
Packaged unit or rooftop unit (RTU)
An air-handling unit, defined as either "recirculating" or "once-through" design, made specifically for outdoor installation. They most often include, internally, their own heating and cooling devices. RTUs are very common in some regions, particularly in single-story commercial buildings.

Plenum space
See also: Plenum chamber
An enclosed space inside a building or other structure, used for airflow. Often refers to the space between a dropped ceiling and the structural ceiling. Distinct from ductwork as a plenum is part of the structure itself.

Thermal zone
A single or group of neighboring indoor spaces that the HVAC designer expects will have similar thermal loads. Building codes may require zoning to save energy in commercial buildings. Zones are defined in the building to reduce the number of HVAC subsystems, and thus initial cost. For example, for perimeter offices, rather than one zone for each office, all offices facing west can be combined into one zone. Small residences typically have only one conditioned thermal zone, plus unconditioned spaces such as unconditioned garages, attics, and crawlspaces, and unconditioned basements.

Variable air volume (VAV) system
An HVAC system that has a stable supply-air temperature, and varies the air flow rate to meet the temperature requirements. Compared to CAV systems, these systems waste less energy through unnecessarily-high fan speeds. Most new commercial buildings have VAV systems.

Source: Wikipedia.



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Section

10

Electrical

Contents

10.0.0 Electrical Basics—AC versus DC

In 1887, direct-current (dc) electricity enjoyed widespread use across the United States, generated by the 121 Edison power stations in existence at that time. The limitations on direct current, which could only be sent about a mile before it began to diminish in power, fostered the development of alternating current (ac) which could be transmitted hundreds of miles before it experienced any loss of power. Developed by George Westinghouse, ac power gradually replaced dc power.

AC power, both voltage and current, swings back and forth in direction, one cycle every rotation, making a sine wave as the magnets in the generator swing north and south and back again. This means that ac systems actually turn off twice during that sine wave.

10.0.1 Role of the Transformer

The role of the transformer is to change or lower the voltage. Most external power lines carry 110 V (volts) ac, but high-voltage lines carry upward of 10,000 V, and the high-voltage lines, in most cases, must be considerably reduced for commercial and residential consumption. AC can be changed in voltage rather easily by using transformers.

10.0.2 A Transformer as a Simple Device

A transformer can be as simple as a device with a square or donut-shaped iron center or core with wire wrapped around each side in different numbers of turns on opposing sides.

10.1.0 Ohm's Law

Ohm's law states that in a simple electric circuit, the voltage equals the electric current multiplied by the resistance. Ohm's law defines the relationship among power, voltage, current, and resistance. Resistance can be thought of as friction as the electrons move through the wire. This resistance is measured in ohms. Ohm's law is represented in the equation

$$V = IR$$

where

V = voltage, V
I = current, A (amperes, amps)
R = resistance, Ω (Greek letter omega, for ohms)
$IR = I \times R$

One ohm is the resistance value through which one volt will maintain a current of one ampere.

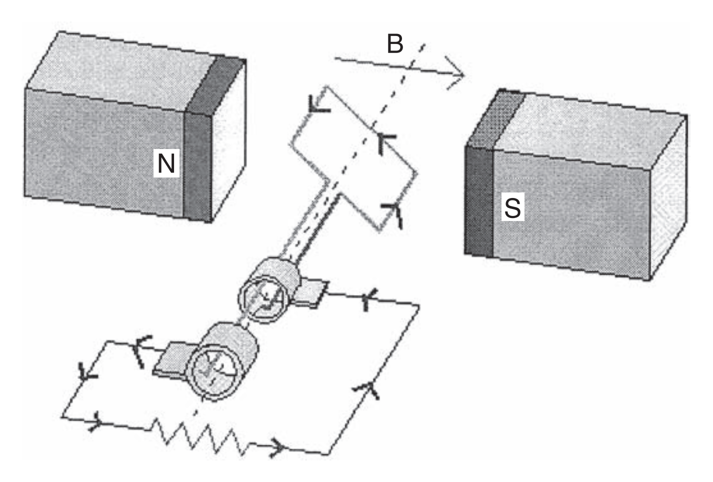
10.1.1 Ohms Equals Volts Divided by Amperes

Watts (W) = volts (V) × amperes (A)
Amperes = volts/ohms, or watts/volts
Volts = watts/amperes, or amperes × ohms

10.1.2 Single-Phase and Three-Phase Electricity

Most electric power is three-phase which is about 150 percent more efficient than single-phase. *Phases* relate to the timing of the magnets passing over the coils in a generator at different times; three-phase electricity is simply a single phase with two extra coils out of phase with the first. With single phase, power can drop to zero in each cycle, but with three-phase, power never drops to zero.

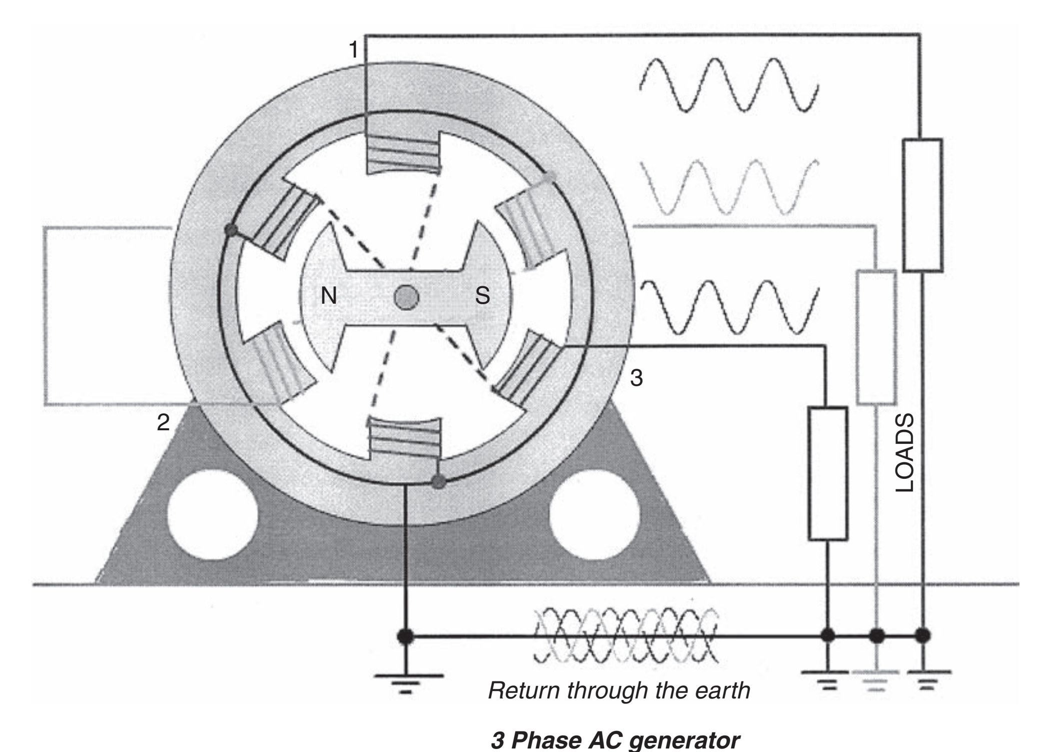
10.1.2.1 Diagram of a Single-Phase Generator



Source: physicshelp.com.

10.1.2.2 Three-Phase Generator Cutaway

This cutaway reveals the generator's three coils. Large commercial generators generate three alternating currents at the same time from the same generator. Each of the currents generated is timed from the other by 33 percent, so, in theory, each phase occurs 120° apart from the other phase.



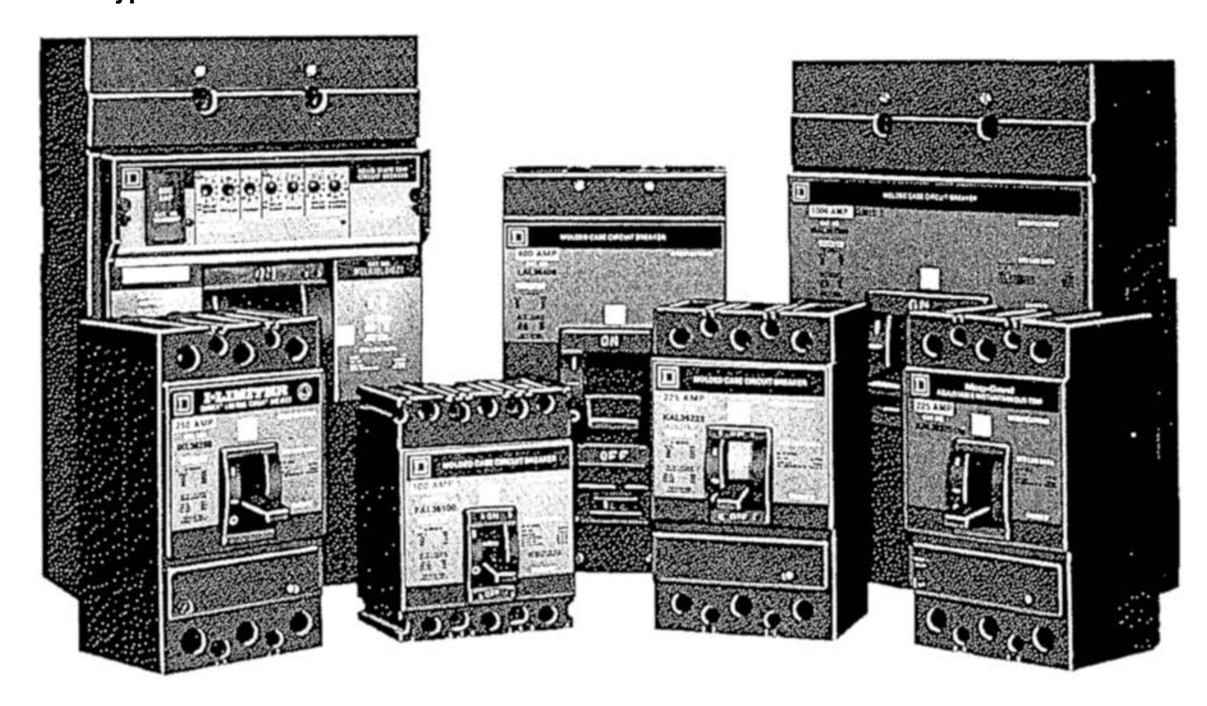
3 Phase AC generator

Source: physicshelp.com.

10.2.0 Circuit Breakers as Overcurrent Protective Devices

Circuit breakers are overcurrent protective devices providing incoming service, feeder, and branch circuit protection. As defined by Underwriters Laboratory (U.L.), a circuit breaker is "a device designed to open and close a circuit by non-automatic means and to open the circuit automatically without injury to itself when properly applied within its rating."

10.2.1 Types of Circuit Breakers



CIRCUIT BREAKERS

Circuit breakers are overcurrent protective devices that are used in an electrical circuit to provide service entrance, feeder and branch circuit protection in accordance with the National Electrical Code NFPA70. The following paragraphs deal with low voltage (600 volts and below) molded case circuit breakers as manufactured by Square D.

DEFINITION

Underwriters Laboratories, Inc. (UL), the National Electrical Manufacturers Association (NEMA) and the National Electrical Code (NEC) define a circuit breaker as "A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically at a predetermined overcurrent without injury to itself when properly applied within its rating."

CIRCUIT BREAKER TYPES

CIRCUIT BREAKER IDENTIFICATION

The catalog numbering system of Square D molded case circuit breakers is relatively easy to learn because it describes the breaker according to type, poles, rating, etc. Catalog Class 600 describes the method to build a catalog number.

All industrial molded case circuit breakers have a highly durable faceplate label which contains application information required in all correspondence with the factory concerning the condition of the breaker for replacement services. Faceplate label information includes catalog number, series number, dual UL/IEC (International Electrotechnical Commission) interrupting ratings, calibration temperature, UL type designation, modifications, electrical accessories, lug data and the manufacturing date code. To view this information, removal of the breaker from the panelboard or switchboard is not necessary.

THERMAL-MAGNETIC

The most widely used overcurrent protection devices are thermal-magnetic circuit breakers. These general purpose circuit breakers are the industry standard. They use bimetals and electromagnetic assemblies to provide both thermal and magnetic overcurrent protection. Their characteristic inverse time tripping is ideally suited for many applications varying from residential loads to heavy industrial loads.

MAGNETIC ONLY

MAG-GARD instantaneous trip circuit breakers are similar in construction to thermal-magnetic breakers, except they provide short circuit protection only. They do not provide any thermal protection and are used in combination with motor starters. MAG-GARD circuit breakers are intended for motor circuits which often have high starting inrush currents.

10.2.1 Types of Circuit Breakers (Continued)

CIRCUIT BREAKERS

MOLDED CASE SWITCH

Molded case switches provide no overcurrent protection and are used as disconnect switches only. Because of their molded case construction they are more compact than conventional disconnect switches and will accept electrical accessories for added flexibility.

Molded case switches are of two types: standard and automatic. Neither provide any overcurrent protection. Continuous current ratings of molded case switches are dependent upon frame size (i.e. FAL36000M is a 100A frame which therefore carries a maximum of 100 amperes).

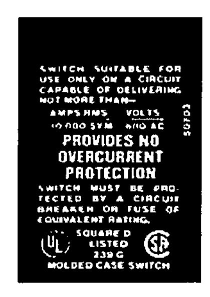


FIGURE 2.2.1

The switches are marked with withstand ratings which specify the amount of rated short circuit current the switch can endure and continue to operate for a short period without sustaining damage, Figure 2.2.1.

STANDARD MOLDED CASE SWITCH

The standard molded case switch is a device without trip elements. It consists of the standard breaker contacts, bussing and lugs for the highest ampere rating in each breaker frame size and is manually operated only. Although these devices are primarily used in motor branch circuits, they need not be horsepower rated because normally their withstand ratings are much greater than the locked rotor currents produced on such circuits. Withstand ratings of standard molded case switches are usually 10,000 amperes.

AUTOMATIC MOLDED CASE SWITCH

This switch will operate the same as nonautomatic switches except at high fault short circuit currents where it will open and protect itself. The automatic switch is available in type FA, KA, LA, MA, NA, PA, and PC frame sizes. Withstand ratings of automatic molded case switches range from 10,000-125,000 amperes.

CURRENT LIMITING

Current limiting circuit breakers do the same job as thermal-magnetic circuit breakers but go one step further by limiting the amount of current that normally passes through a breaker during a severe fault. Square D I-LIMITER current limiting circuit breakers were the first in the industry to offer current limitation without fuses. I-LIMITER's are generally used as main circuit breakers to allow the use of lower interrupting capacity rated breakers downstream. They are discussed in detail in Section 2.5.

SOLID STATE TRIP

Solid state trip circuit breakers use current transformers and solid state circuitry to measure current levels and trip the circuit breaker at predetermined times. Solid state breakers are especially useful for coordination purposes because of their many trip setting adjustments.

2.3 CONSTRUCTION

Several key components are common to all circuit breakers. These are: the molded case, trip elements, an operating mechanism and line and load connectors. These and other components found in circuit breakers are as follows:

MOLDED CASE

The function of the molded case is to provide an insulated housing to mount all of the circuit breaker components (see Figure 2.3.1). The case is molded from a phenolic material which combines high dielectric strength with ruggedness. Maximum current, voltage, and interruption capacity determine the size and strength of the molded case. In general the higher the ratings the stronger the case must be.

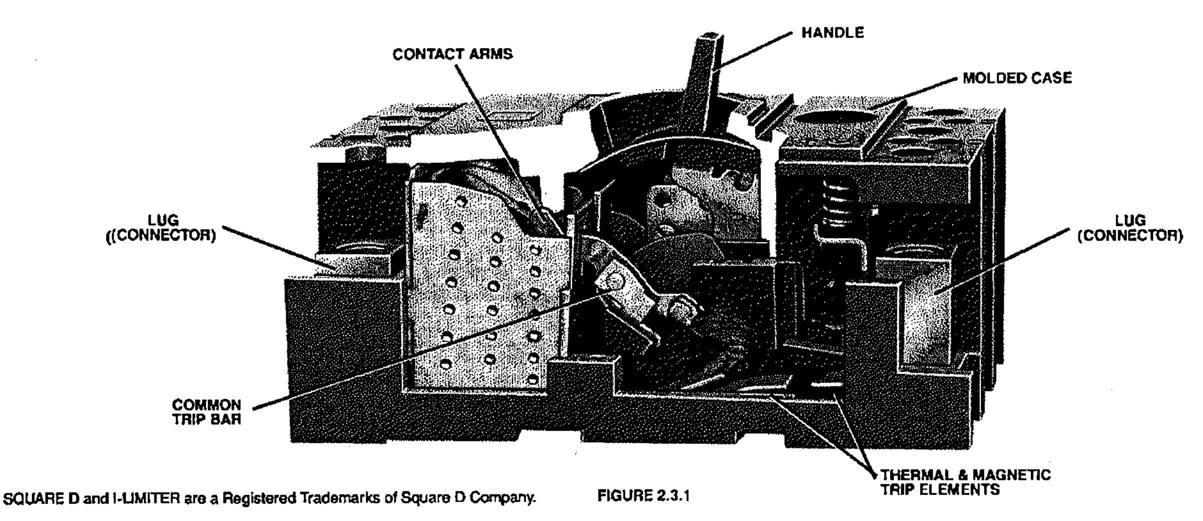


FIGURE 2.3.1

By permission, Square D Schneider Electric, Greenville, WI.

10.2.2 Trip Elements in a Circuit Breaker

TRIP ELEMENTS

An overcurrent trip element is a device with which any given pole of a circuit breaker detects an overcurrent and transmits the energy necessary to trip the circuit breaker automatically. This can be done in three ways: thermally, magnetically, or electronically.

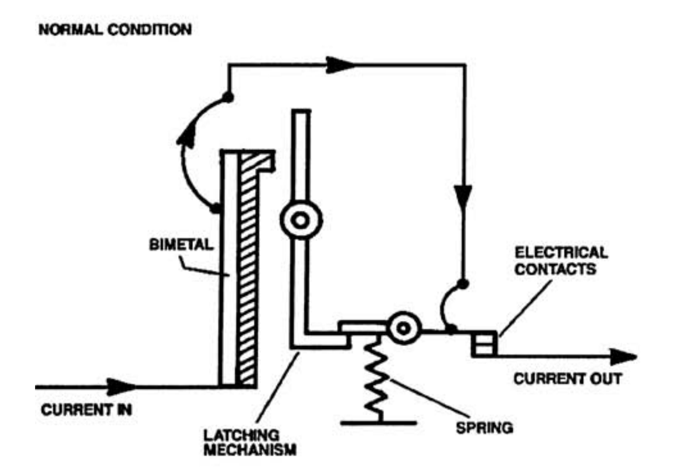
THERMAL TRIP

The thermal trip element consists of a bimetal constructed from metals of dissimilar properties bonded together. Due to the different rates of expansion of these metals, the heat generated by current passing through them causes the bimetal to bend. The bending force of the bimetal is then used to trip the circuit breaker. (See Figure 2.3.2).

These elements have inverse time characteristics, (i.e., the tripping time decreases as the magnitude of the current increases). For example: On light overloads at 135% rating, it might take 200 seconds to trip the breaker and at 500% rating, it might take only 2 seconds to trip.

MAGNETIC TRIP

The magnetic trip or instantaneous trip, is that part of a trip unit which contains an electromagnetic assembly to trip the circuit breaker instantaneously at or above a predetermined value of the current. All Square D thermal-magnetic and magnetic only circuit breakers and automatic molded case switches have a magnetic trip element in each pole. This element responds to a given value of overcurrent and is independent of the thermal element. (See Figure 2.3.3).



THERMAL TRIP CONDITION

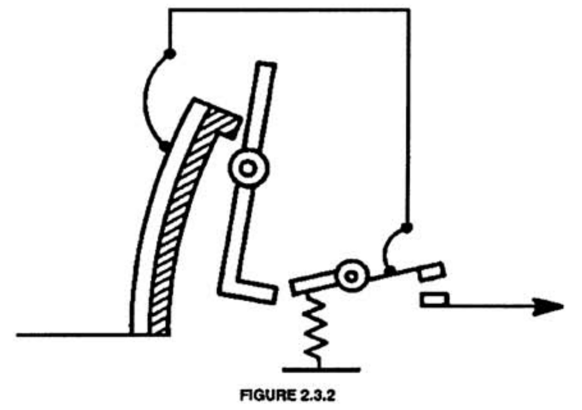
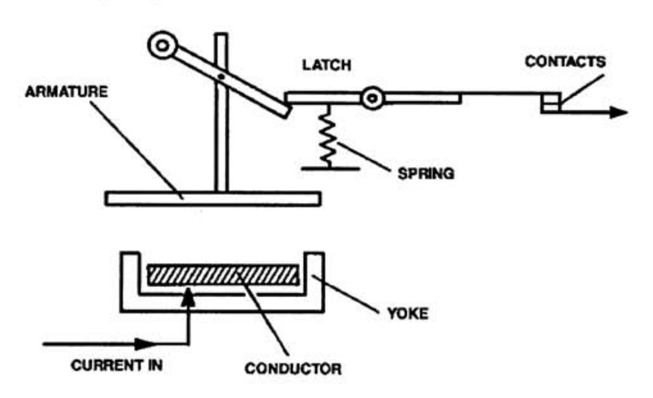
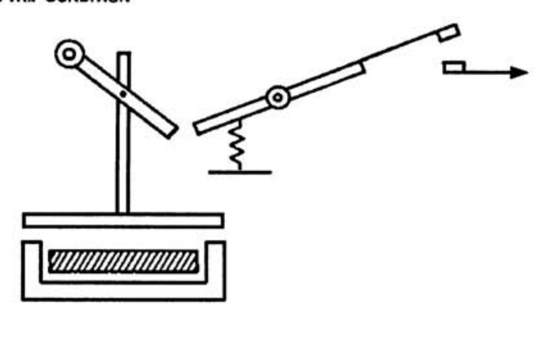


FIGURE 2.3.2

NORMAL CONDITION



MAGNETIC TRIP CONDITION



ON HIGH OVERCURRENTS, MAGNETIC FORCES DRAW THE ARMATURE DOWN TO THE YOKE AND CAUSE THE LATCH TO RELEASE

FIGURE 2.3.3

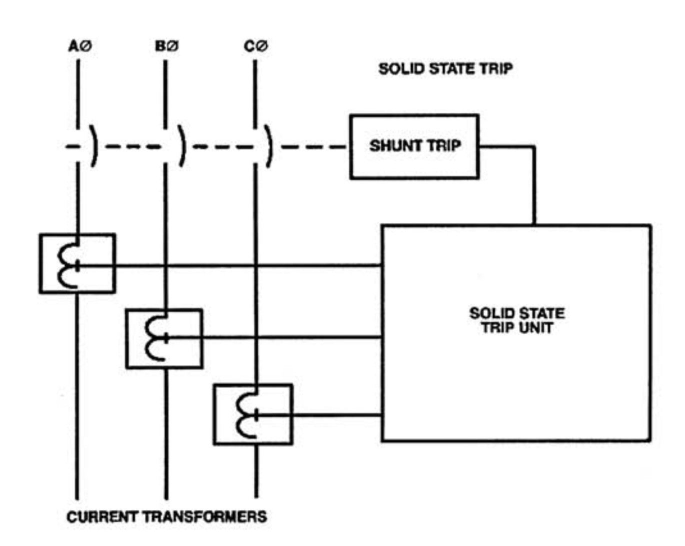
Both fixed and adjustable type magnetic trip elements are available. 100A frame breakers and below have fixed magnetic trip elements. Circuit breakers larger than 100A frame have adjustable magnetic trip elements.

A feature of Square D circuit breakers is the single control adjustment of the magnetic trip. This one adjustment will set all poles simultaneously and at the same value of tripping current. The adjustment is continuous from approximately 5-10 times the breaker's continuous current rating. The only exception is the IL current limiting circuit breaker with three individual adjustments.

SOLID STATE TRIP

Solid state trip circuit breakers offer much greater reliability and accuracy in sensing overcurrents and initiating tripping of the circuit breaker. Through the use of current transformers and solid state components, current levels are measured and timed, then compared to predeter-

10.2.2 Trip Elements in a Circuit Breaker (Continued)



mined values. When the predetermined current and time levels have been reached, the solid state trip unit sends a signal to an internal tripping solenoid which trips the circuit breaker.

The ME, NE, PE and SE family of solid state trip circuit breakers are available from 225A through 4000A frame sizes. Individual current ratings are determined by interchangeable rating plugs. Rating plug values determine the continuous current rating of the breaker.

Because of the reliable accuracy of solid state components, the circuit breaker will trip at the same point time after time. In addition, solid state trip breakers offer the versatility of adjustments which can be made to various discrete portions of the time-current characteristic tripping curve. Trip unit adjustments are available for various functions.

OPERATING MECHANISM

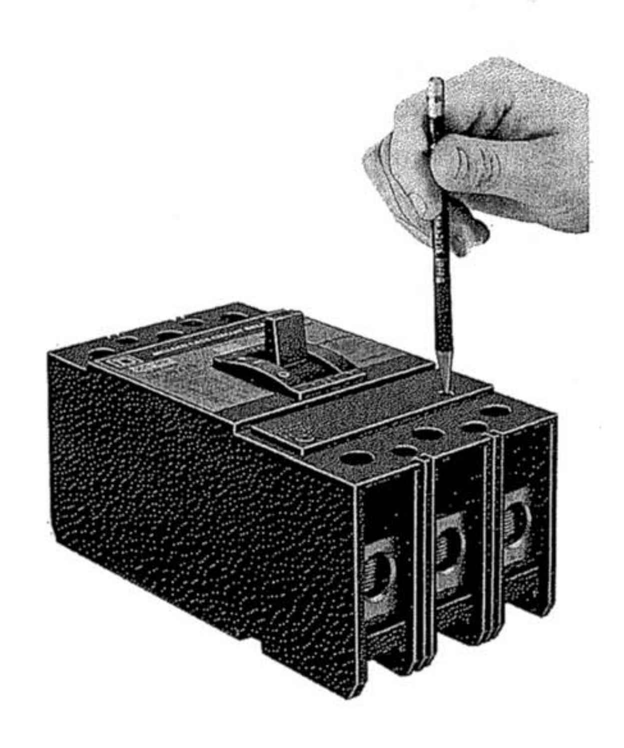
Most single and multi-pole circuit breakers have a single operating handle. This handle acts directly through the operating mechanism against the contact arms. Multiple pole circuit breakers have a common trip bar assuring positive action for all poles on manual and automatic operation.

Square D circuit breakers have a trip-free, over-center toggle mechanism which allows the circuit breaker to trip even though the handle may be locked closed by means of a padlock attachment. Without this attachment the handle will assume a central position between ON and OFF when the circuit breaker trips.

PUSH-TO-TRIP

Push-To-Trip is a standard feature of Square D industrial circuit breakers which permits the operator to manually trip the circuit breaker without exposing the operator to live parts.

During normal operations the handle will manually open and close the circuit breaker contacts but will not "exercise" the tripping mechanism. In order to do this and also exercise any associated accessories, the yellow Push-To-Trip button on the face of the breaker must be depressed. In addition, maintenance personnel use it to check the alarm circuit, emergency circuit, and motor sequencing operations, and to diagnose electrical problems. Also, once the breaker is tripped, the alignment of external handle operating mechanisms can be checked to assure resetting capabilities. The Push-To-Trip feature assures the user that the breaker mechanism is in operable condition since all its operating parts are exercised when tested in this manner.

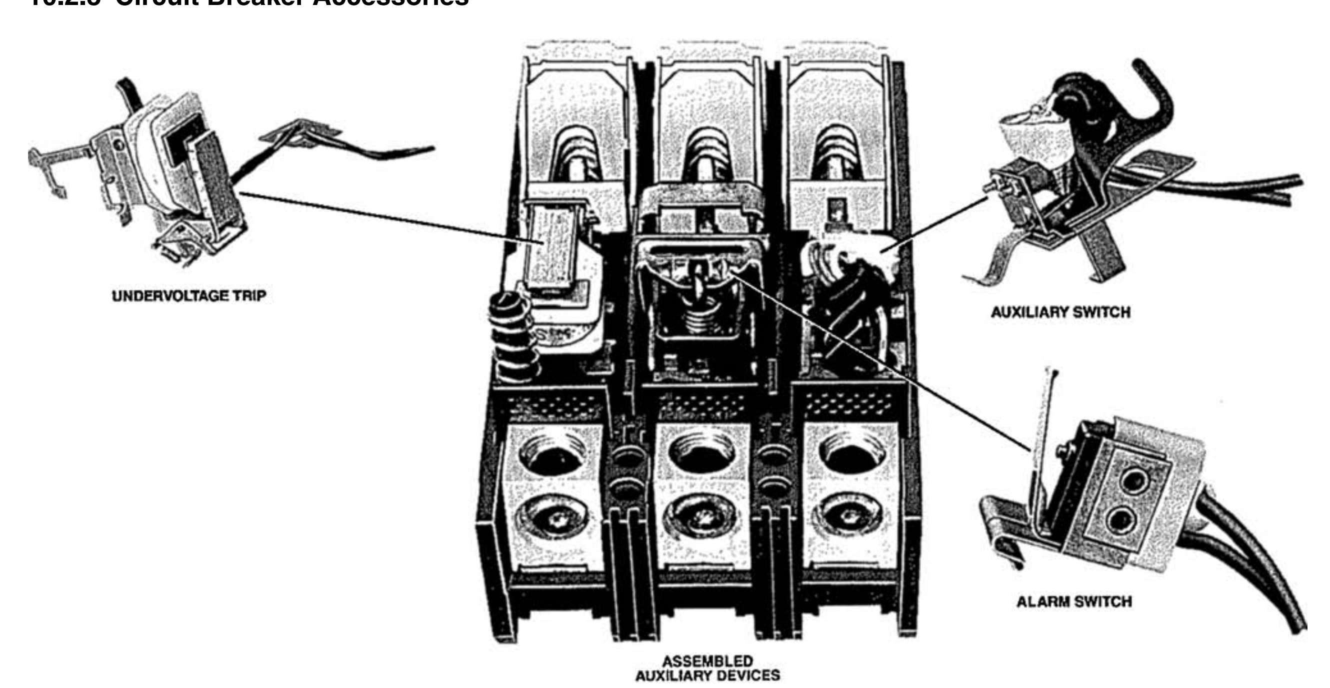


LINE & LOAD CONNECTIONS

All circuit breakers have provisions for making line and load connections into an electrical circuit. Compression-type lugs or mechanical-type lugs can be provided for all breakers up to 2500A frame size (except SE breakers). All terminal lugs are UL listed for their proper application and are listed for either Al/Cu or Cu only cable.

Additionally, there are plug-on connectors similar to those used on residential breakers. They are designed for rapid installation and removal of the breakers. All Square D terminal connectors are rigorously tested. These terminal connections must not only pass UL tests but must also meet Square D quality requirements.

10.2.3 Circuit Breaker Accessories



ACCESSORIES

A wide range of accessories are available for circuit breakers to make them fit a particular application. Accessories for type LA, MA, NA, NE, PA, PE, PC breakers may be field installed. Refer to Catalog Class 690. These accessories are available on most Square D circuit breakers.

SHUNT TRIP

A shunt trip is a mechanism which trips the circuit breaker by means of a solenoid which is energized from a separate source or power source. The solenoid circuit is closed by an external relay, switch or other means. Most shunt trip coils do not have continuous current rating, so a coil clearing switch is included to break the solenoid circuit when the circuit breaker opens. Standard shunt trips are rated 12, 24, 48, 125, and 250 volts dc and 120, 208, 240, 277 and 480 volts AC. Other voltage ratings are available upon special request. The shunt trip is available on residential/commercial breakers in 1, 2 and 3-pole configuration. For industrial breakers, the shunt trip is available in 2 or 3-pole versions. The control leads for the shunt trip are color coded black.

UNDERVOLTAGE TRIP

The undervoltage trip is a device which trips the circuit breaker automatically when the main circuit voltage falls below 35-70% of its specified value. The breaker cannot be returned to service until the voltage returns to at least 85% of rated value. These trips are available in the same breaker as the shunt trip. They are supplied as standard in the same voltage ratings as the shunt trip except that undervoltage trips rated above 24 volts dc or 240 volts AC are suppled with external resistors. The control wires for undervoltage trips are color coded brown. An undervoltage trip time delay unit is available for the undervoltage trip accessory. Its adjustable time delay feature allows the undervoltage trip to ignore momentary voltage fluctuations without tripping the breaker.

NOTE: The shunt trip and undervoltage trip cannot be supplied in the same pole of the circuit breaker, but only one of these devices is necessary to perform both purposes when they are installed in the same electrical system. Normally closed contacts, such as those used in stop buttons, can be installed in the control circuit to open the breaker via an undervoltage trip in a manner similar to a shunt trip.

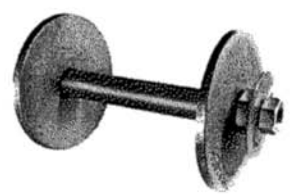
AUXILIARY SWITCHES

An auxiliary switch is one which is mechanically operated by the circuit breaker blades and is used for signaling, interlocking, and indicating contact position. An "A" type contact is one which is open when the breaker contacts are open. The "B" type contact is closed when the breaker contacts are open. Auxiliary switches are available in the same combination as shunt and undervoltage trip. They are rated for 10 amperes at 120/240VAC, 4 amperes for 120VAC ampere loads, ½ ampere at 125Vdc and ¼ ampere at 250Vdc.

Control leads for "A" contacts are color coded yellow and the "B" contacts are blue. The common leads are color coded blue with yellow stripes. When two or more of the same contacts are required (two N.O. or N.C.), the color coding remains as above with the leads identified by numbered tabs.

10.2.3 Circuit Breaker Accessories (Continued)

Labor studies have shown that an 80% saving in installation time is not uncommon when comparing I-LINE busway with older multi-bolt types of feeder or plug-in busway. Similar savings are realized when installing I-LINE busway in the place of wire and conduit. Both I-LINE feeder and I-LINE plug-in busway use the same joint which allows maximum flexibility. Plug-in sections can be inserted in feeder runs where power tap-off is required. Or feeder sections may be interspersed in runs consisting predominantly of plug-in busway. The tremendous labor savings realized when installing I-LINE busway rather than conventional busway or wire and conduit installations is, from the contractors' viewpoint, one of its most important advantages.



All I-LINE busway is UL listed for hanging on 10′0″ horizontal centers or 16′0″ vertical centers. This eliminates half the hangers required by some competitive makes.

SHORT CIRCUIT BRACING

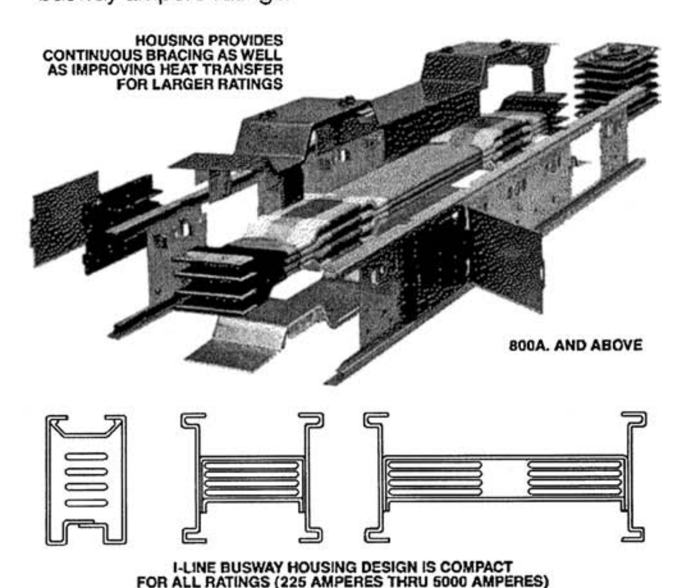
During a surge of current resulting from a low resistance fault either in the busway or in the equipment fed by the busway, the conductors carrying the fault current are subjected to extremely large physical forces. These forces are the result of the interaction of the lines of magnetic flux which surround any current flow. For currents in the range that might be encountered during a bolted fault on a large busway system, these forces may reach values of several tons per lineal foot of conductor. For a 3 phase system, there is always one conductor which is being forced away from the other two by these fault current forces, just as two magnets are repelled by each other when poles of like polarity are adjacent. To prevent physical damage to the busway, some means of restraining these forces must be provided.

All I-LINE busway is built with special attention to the physical bracing needs which high level short circuit currents demand.

In I-LINE plug-in busway, special molded support insulators are located at every plug-in opening (10 per 10′0″ length). It is significant that this support insulator is located at the most critical area—the plug-in opening. Without it, movement of the bus bars might damage plug-in units installed on the busway, even though the busway itself is able to withstand the fault and may show no apparent damage. This is why UL 857 "Standard for Busway and Associated Fittings" requires that the short circuit rating of any plug-in busway be determined by testing two lengths of busway in series: one of which must have plug-in units installed on it.

I-LINE II busway (800 amperes and above) also includes special housing details which provide even higher short circuit bracing throughout the entire length of each piece of busway (both feeder and plug-in).

For 225 ampere through 600 ampere busway, short circuit ratings of 22,000 amperes are standard. Optional construction offers a 42,000 ampere short circuit rating for 400 ampere and 600 ampere plug-in busway. Busway rated 800 amperes and above offers standard short circuit ratings of from 50,000 amperes to 200,000 amperes (depending on the specific busway rating selected). An optional high short circuit busway is also offered, which differs from the standard design only in the bracing details and in the material used to mold the support insulator at the plug-in opening. This high short circuit busway (cataloged APH and CPH) increases the standard short circuit ratings by 25,000-50,000 amperes in the majority of busway ampere ratings.



I-LINE BUSWAY HOUSING DESIGN IS COMPACT FOR ALL RATINGS (225 AMPERES THRU 5000 AMPERES)

INSULATION

All primary insulation in I-LINE busway is Class B material, capable of satisfactory operation at temperatures up to 130°C. In both feeder busway and plug-in busway, double layers of MYLAR* polyester film are used. The use of Class B insulation is intended primarily as a means of extending insulation life under normal operating conditions. Nearly all insulating materials age more quickly when the operating temperature at which they are used approaches the allowed maximum. Most other busway designs use PVC (polyvinyl chloride), butyl rubber, plastic tape or some other Class A 105°C material. Because of this, I-LINE busway can be used in many areas of higher than normal ambient temperature without the derating required for other makes.

10.2.4 How Typical Wattage Increases during a Surge

Device	Typical wattage	Surge Wattage
Light bulb	60 watts	60 watts surge
Fan	75 watts	150 watts surge
Small black/white television	100 watts	150 watts surge
Color television	300 watts	400 watts surge
Home computer and monitor	400 watts	600 watts surge
Electric blanket	400 watts	400 watts surge
Microwave oven	750 watts	1,000 watts surge
Furnace fan	750 watts	1,500 watts surge
Refrigerator	1,200 watts	2,400 watts surge
Well pump	2,400 watts	3,600 watts surge
Electric water heater	4,500 watts	4,500 watts surge
Whole-house A/C or heat pump	15,000 watts	30,000 watts surge

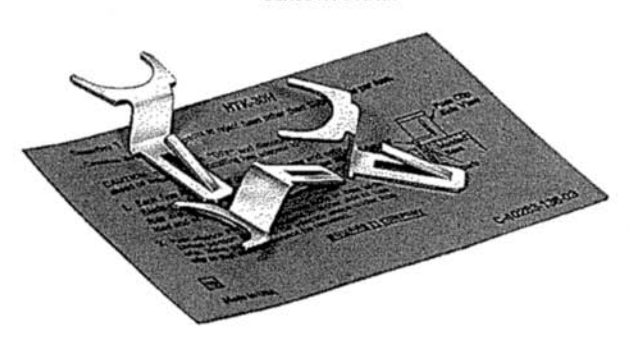
Source: Howitworks.com.

10.3.0 Safety Switches—General Duty (GD) and Heavy-Duty (HD) Service

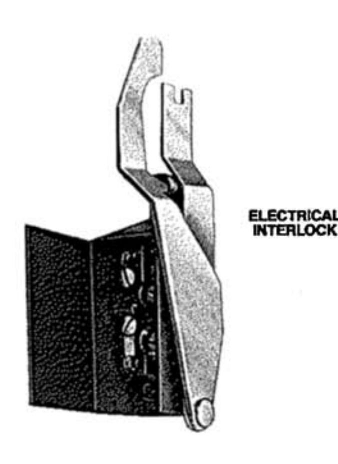
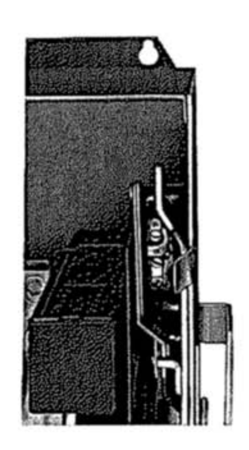
ACCESSORIES

Accessories available for field installation include Class R fuse kits, fuse pullers, insulated neutrals with grounding provisions, equipment grounding kits, watertight hubs for use with TYPE 4, 4X, 5 stainless or TYPE 12 switches, and interchangeable bolt-on hubs for TYPE 3R switches.


CLASS R FUSE KIT



Electrical interlock consists of auxiliary contacts for use where control or monitoring circuits need to be switched in conjunction with the safety switch operation. Kits can be either factory or field installed, and they contain either one normally open and one normally closed contact or two normally open and two normally closed contacts. The electrical interlock is actuated by a pivot arm which operates directly from the switch mechanism. The electrical interlock is designed so that its contacts disengage before the blades of the safety switch open and engage after the safety switch blades close.


ELECTRICAL INTERLOCK


SQUARE D is a Registered Trademark of Square D Company.

GENERAL DUTY SWITCHES

General duty switches for residential and light commercial applications are used where operation and handling are moderate and where the available fault current is 10,000 RMS symmetrical amperes or less. Square D general duty safety switches exceed this specification in that they are UL listed for application on systems having up to 100,000 RMS symmetrical amperes of available fault current when Class R fuses and Class R fuse kits are used. Class T fusible switches are also available in 400, 600 and 800 ampere ratings. These switches accept 300VAC Class T fuses only. Some examples of general duty switch application include residential, farm, and small business services entrances, and light duty branch circuit disconnects.

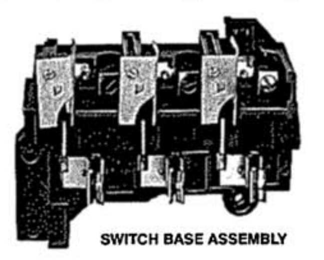

GENERAL PURPOSE TYPE 1


RAINPROOF TYPE 3R

General duty switches are rated up to 600 amperes at 240 volts AC in general purpose (TYPE 1) and rainproof (TYPE 3R) enclosures. These switches are horsepower rated and capable of opening a circuit up to six times the rated current of the switch.

SWITCH BLADES AND JAWS

All current carrying parts of general duty switches are plated to minimize oxidation and reduce heating. Switch jaws and blades are made of copper for high conductivity.


SWITCH BASE ASSEMBLY


FUSE BASE ASSEMBLY



FUSE CLIP AND LOAD LUG

By permission, Square D Schneider Electric, Greenville, WI.

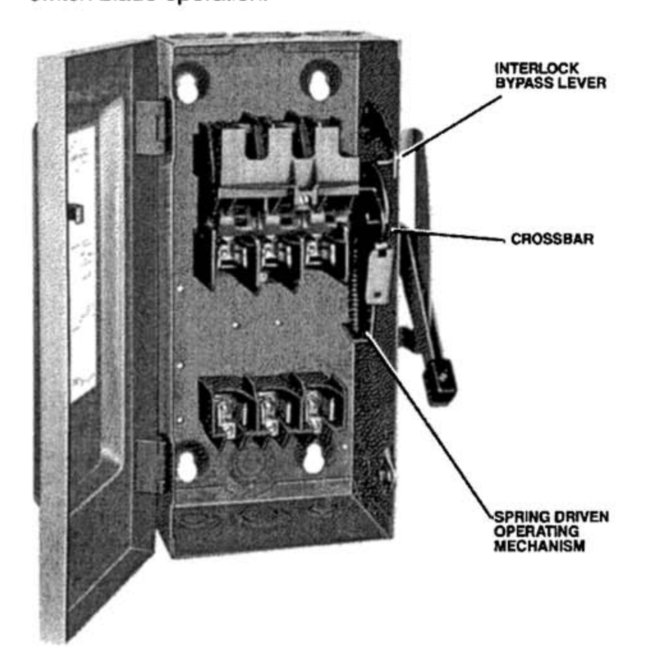
10.3.0 Safety Switches—General Duty (GD) and Heavy-Duty (HD) Service (Continued)

OPERATING MECHANISM & COVER LATCHING

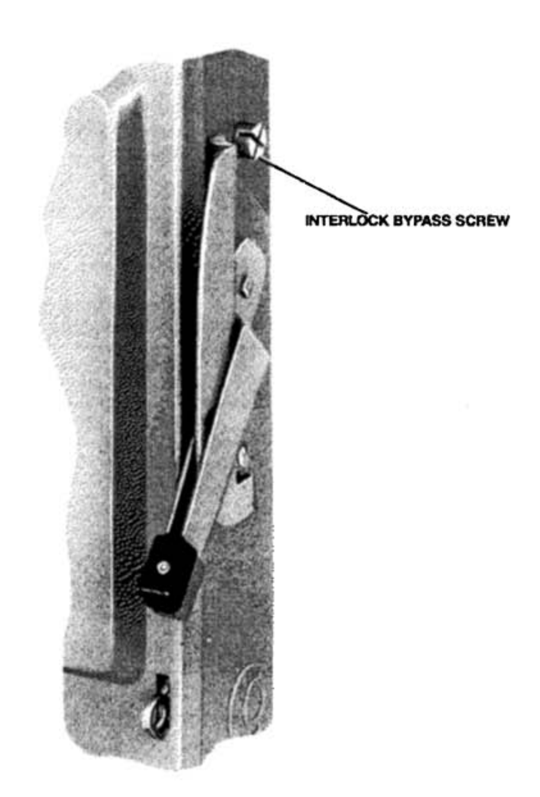
Square D heavy duty safety switches have a spring driven quick-make, quick-break mechanism. A quick-breaking action is necessary if the switch is to be safely switched OFF under a heavy load.

The spring action, in addition to making the operation quick-make, quick-break firmly holds the switch blades in the ON or OFF position. The operating handle is an integral part of the switching mechanism and is in direct control of the switch blades under normal conditions.

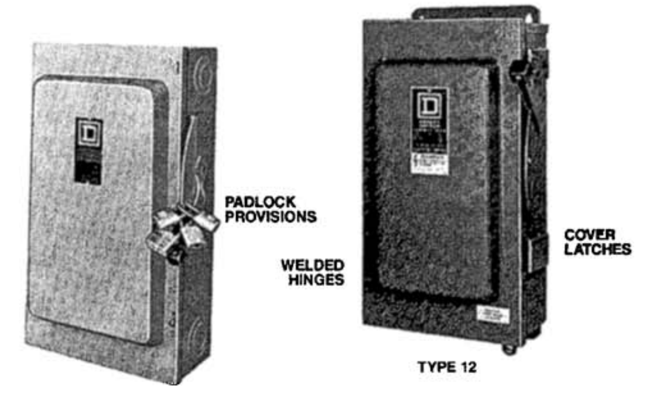
A one-piece cross bar, connected to all switch blades, adds to the overall stability and integrity of the switching assembly by promoting proper alignment and uniform switch blade operation.



Dual cover interlocks are standard on all heavy duty switches (except TYPE 7 and 9 which feature bolted covers.) The dual interlock prevents the enclosure door from being opened when the switch handle is in the ON position and prevents the switch from being turned ON while the door is open. A means of bypassing the interlock is provided to allow the switch to be inspected in the ON position.



TYPE 1, TYPE 4, 4X, 5 stainless, and TYPE 12 and 12K enclosures feature four point latching doors. This means that, with the door closed and the switch ON, the door is held firmly to the enclosure near each of the four corners by hinges and latching mechanisms. This provides additional protection should a fuse rupture occur within the enclosure. Heavy duty switches can be padlocked in the OFF position with up to three padlocks.

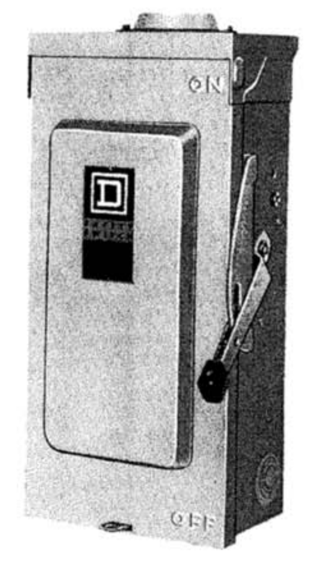


By permission, Square D Schneider Electric, Greenville, WI.

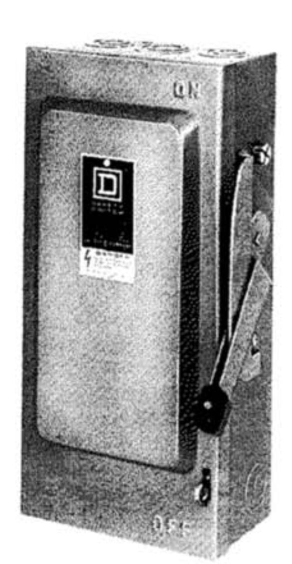
10.3.1 Safety Switches with Dustproof Enclosures

ENCLOSURE

Square D heavy duty switches are available in a variety of enclosures which have been designed to conform to specific industry requirements based upon the intended use. Sheet metal enclosures (eg., TYPE 1) are constructed from cold-rolled steel which is phosphatized and finished with an electrodeposited enamel paint. The TYPE 3R rainproof and TYPE 12 and 12K dusttight enclosures are manufactured from galvannealed sheet steel and painted to provide better weather protection. The TYPE 4, 4X and 5 enclosures are made of corrosion resistant Type 304 stainless steel; no painting required. TYPE 7 & 9 enclosures are cast from copper-free aluminum and finished with an enamel paint.



TYPE 3R HEAVY DUTY SWITCH



TYPE 1 HEAVY DUTY SWITCH

TYPE 4, 4X, 5 stainless steel switches are designated dusttight, watertight and corrosion resistant and designed for indoor and outdoor use. Common applications include commercial type kitchens, dairies, canneries, and other types of food processing facilities, as well as areas where mildly corrosive liquids are present. All TYPE 4, 4X and 5 stainless steel enclosures are provided without knockouts. Use of watertight hubs is required. Available switch ratings are 30 through 600 amperes.

TYPE 1 switches are general purpose and designed for use indoors to protect the enclosed equipment from falling dirt and personnel from live parts. Switches rated through 200 amperes are provided with ample knockouts. 400 through 1200 ampere switches are provided without knockouts.

TYPE 3R switches are designated "rainproof" and are designed for use outdoors.

TYPE 3R enclosures for switches rated through 200 amperes have provisions for interchangeable bolt-on hubs at the top endwall. TYPE 3R switches rated higher than 200 amperes have blank top endwalls. Knockouts are provided (below live parts only) on enclosures for 200 ampere and smaller TYPE 3R switches. TYPE 3R switches are available in ratings through 1200 amperes.



TYPE 4, 4X, 5 STAINLESS HEAVY DUTY SWITCH

10.3.1 Safety Switches with Dustproof Enclosures (Continued)

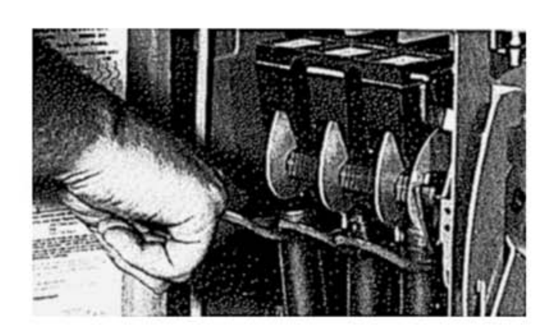
SAFETY SWITCHES

TYPE 12 and TYPE 12K switches are designated dusttight (except at knockout locations on TYPE 12K) and are designed for indoor use. In addition, Square D TYPE 12 safety switches are designated as raintight for outdoor use when the supplied drain plug is removed. Common applications include heavy industries where the switch must be protected from such materials as dust, lint, flyings, oil seepage, etc. TYPE 12K switches have knockouts in the bottom and top endwalls only. Available switch ratings are 30 through 600 amperes in TYPE 12 and 30 through 200 amperes in TYPE 12K.



TYPE 12 HEAVY DUTY SWITCH

All Square D TYPE 4, 4X, 5, TYPE 12, and TYPE 12K switch enclosures feature positive sealing to provide a dusttight and raintight (watertight with stainless steel) seal. Enclosure doors are supplied with oil resistant gaskets. Switches rated 30 through 200 amperes incorporate unique spring loaded, quick-release latches. 400 and 600 ampere switches feature single-stroke sealing by operation of a cover mounted handle. 30, 60 and 100 ampere switches in these enclosures are provided with factory installed fuse pullers.



FUSE PULLERS

INTERLOCKED RECEPTACLES

60 ampere TYPE 1 and TYPE 12 switches with either a HUBBELLOCK or ARKTITE interlocked receptacle are also provided. This receptacle provides a means for connecting and disconnecting loads directly to the switch. A non-defeating interlock prevents the insertion or removal of the receptacle plug while the switch in is the ON position. It also prevents operation of the switch if an incorrect plug is used.



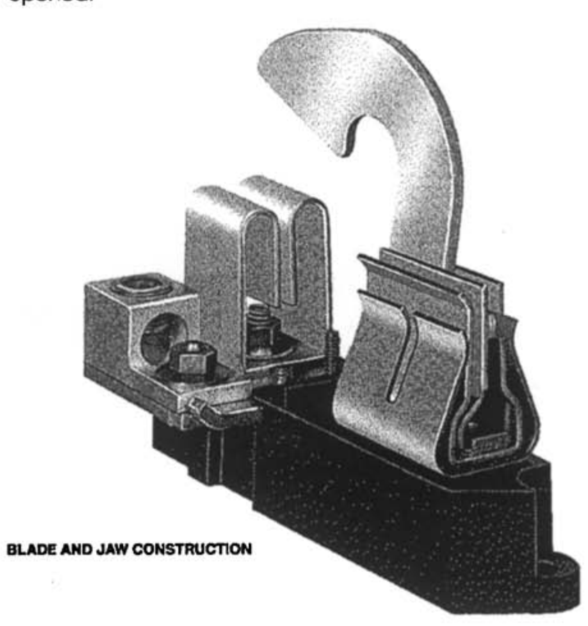
TYPE 12 SAFETY SWITCH WITH CROUSE-HINDS ARKTITE INTERLOCKED RECEPTACLE

From Square D Company.

10.3.2 Switch Insulating Materials, Switch Blade, and Jaw Components

SWITCH BLADE AND JAWS

Two types of switch contacts are used by the industry in today's safety switches. One is the "butt" contact; the other is a knife-blade and jaw type. On switches with knife-blade construction, the jaws distribute a uniform clamping pressure on both sides of the blade contact surface. In the event of a high-current fault, the electromagnetic forces which develop tend to squeeze the jaws tightly against the blade. In the butt type contact, only one side of the blades contact surface is held in tension against the conducting path. Electromagnetic forces due to high current faults tend to force the contacts apart, causing them to burn severely. Consequently, Square D uses the knife blade and jaw type construction on all heavy duty switches. The action of the blades moving in and out of the jaws aids in cleaning the contact surfaces. All current-carrying parts of these switches are plated to reduce heating by keeping oxidation at a minimum. Switch blades and jaws are made of copper for high conductivity. Spring-clamped blade hinges are another Square D feature that help assure good contact surfaces and cool operations. "Visible blades" are utilized to provide visual evidence that the circuit has been opened.



BLADE AND JAW CONSTRUCTION

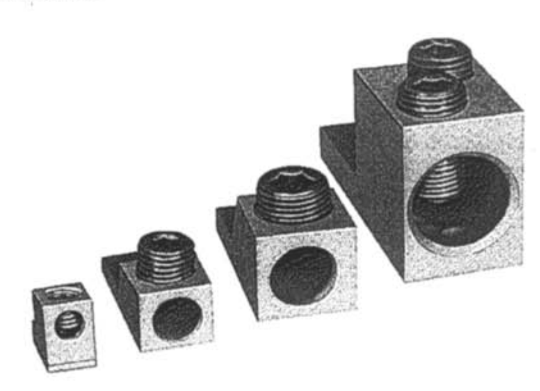
FUSE CLIPS

Fuse clips are plated to control corrosion and to keep heating to a minimum. All fuse clips on heavy duty switches have steel reinforcing springs for increased mechanical strength and firmer contact pressure.



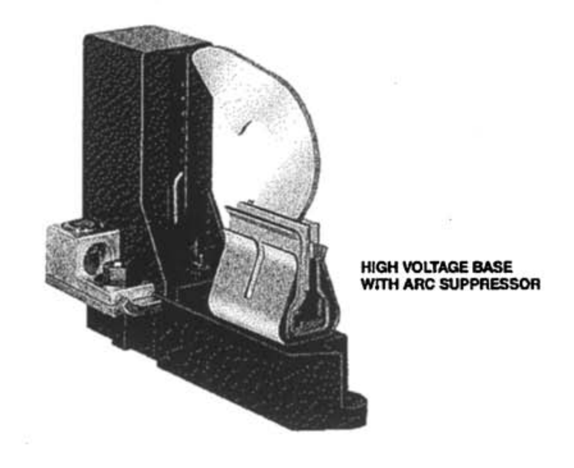
TERMINAL LUGS

The complete heavy duty switch line has front removable, screw-type terminal lugs. All switch lugs are suitable for copper or aluminum wire except TYPE 4, 4X, 5 stainless and TYPE 12 & 12K switches which have all copper current carrying parts and lugs designated for use with copper wire only. Heavy duty switches are suitable for the wire sizes and number of wires per pole as listed in tables 3.1.1 and 3.1.2.



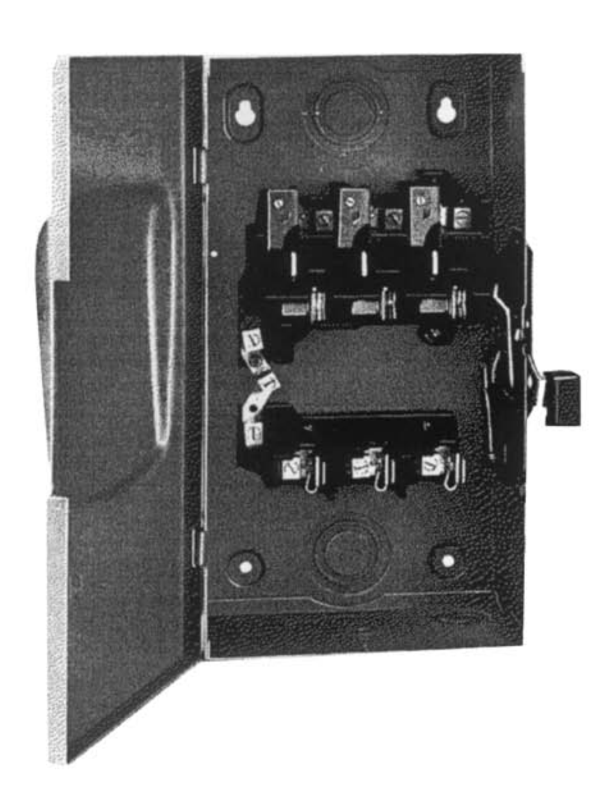
INSULATING MATERIAL

As the voltage rating of switches is increased, arc suppression becomes more difficult and the choice of insulation material becomes more critical. Arc suppressors used by Square D consist of a housing made of insulation material and magnetic suppressor plates when required. All arc suppressor materials have been thoroughly tested to assure proper control and extinguishing of arcs.



HIGH VOLTAGE BASE WITH ARC SUPPRESSOR

10.3.3 General Duty Switch Enclosure Terminal Lug Data



Where required, a steel reinforcing spring increases the mechanical strength of the jaws and contact pressure between the blade and jaw. Good pressure contact maintains the blade-to-jaw resistance at a minimum, which in turn, promotes cool operation. All general duty switch blades feature visible blade construction. With the door open, there is visually no doubt when the switch is OFF.

FUSE CLIPS
Fuse clips are plated to control corrosion and keep heating to a minimum. Where required, steel reinforcing springs are provided to increase the mechanical strength of the fuse clip. The result is a firmer, cooler connection to the fuses as well as superior fuse retention.

TERMINAL LUGS
All Square D general duty safety switches are furnished with mechanical set screw lugs which are suitable for aluminum or copper conductors.

GENERAL DUTY — TERMINAL LUG DATA

Ampere Rating	Conductors Per Phase	Wire Range Wire Bending Space Per NEC Table 373-6	Lug Wire Range
30 Line Load	1 1	#12-6 AWG (Al) or #14-6 AWG (Cu) #14-8 AWG (Al/Cu)	#12-6 AWG (Al) or #14-6 AWG (Cu)★ #14-8 AWG (Al/Cu)
60	1	#10-3 AWG (Al) or #14-3 AWG (Cu)	#10-2 AWG (Al) or #14-2 AWG (Cu)
100	1	#12-1 AWG (Al) or #14-1 AWG (Cu)	#12-1/0 AWG (Al) or #14-1/0 AWG (Cu)
200	1	#4 AWG-250 MCM (Al/Cu)	#4 AWG-300 MCM (Al/Cu)
400	2	#1/0 AWG-250 MCM (Al/Cu)	(1) #1 AWG-600 MCM (Al/Cu) (2) #1 AWG-250 MCM (Al/Cu)
600	2	#4 AWG-500 MCM (Al/Cu)	#4 AWG-600 MCM (Al/Cu)
800	3	#3/0 AWG-500 MCM (Al/Cu)	#3/0 AWG-500 MCM (Al/Cu)

★Excluding #8 AWG solid.

10.4.0 Motor Control Centers and Starters

A motor control center is an assembly of motor starters and other devices to reverse motors, adjust speed, regulate torque, and provide overload protection. Motor starters are electromagnetic or electronic devices employed to start and stop an electric motor. There are various types of starters:

- Direct-on-line (DOL) starters connect the electric motor directly to the power source, thereby transferring full power from that source directly to the motor.
- A motor soft starter temporarily reduces the load and torque from the power source to the motor during start-up, thereby reducing the strain on the motor.
- Reversing starters are composed of two DOL circuits, one to provide clockwise rotation and another to provide counterclockwise rotation.

Motor control centers also include devices for regulating motor speed.

- Adjustable-speed drives (ASDs) or variable-speed drives (VSDs) allow some motors to operate fans and pumps, as two such examples, at different speeds.
- VFD is similar to an ASD and operates on the principle of varied voltage; it is often referred to as a variable-voltage variable-frequency drive. This VFD is often used on fans in large commercial buildings as an energy-saving device.

10.5.0 Ground Fault Protection and Ground Fault Circuit Interrupters (GFCIs)

A ground fault occurs when an unintended path is established between an ungrounded conductor and ground, or an electrical device. This type of situation can occur not only from worn or defective electrical equipment but from equipment in good order that is misused, therefore safety concerns dictate the use of GFIs to protect workers and homeowners.

10.5.1 Effects of Current on a Human Body

GROUND FAULT PROTECTION FOR PEOPLE

Ground fault protection for people is a subject of interest to all of us, both personally and professionally. A ground fault exists when an unintended path is established between an ungrounded conductor and ground. This situation can occur not only from worn or defective electrical equipment but also from accidental misuse of equipment that is in good working order.

Will a conventional overcurrent device (fuse or circuit breaker) detect a ground fault and open the circuit before irreparable harm is done? Before we can answer this question, we need to take a look at the effects of current on the human body.

EFFECTS OF CURRENT ON THE HUMAN BODY

Hand-to-hand body resistance of an adult lies between 1,000 and 4,000 ohms, depending on moisture, muscular structure and voltage. The average value is 2,100 ohms at 240VAC and 2,800 ohms at 120VAC.

Using Ohm's law, the current resulting from the above average hand-to-hand resistance values is 114 milliamperes (0.114 amperes) at 240VAC and 43 milliamperes (0.043 amperes) at 120VAC. The effects of 60 Hz alternating current on a normal healthy adult are as follows (note that current is in milliamperes, or 1/1000 amperes):

More than 5 mA — generally painful shock
More than 15 mA — sufficient to cause "freezing" to the circuit for 50% of the population
More than 30 mA — breathing difficult (possible suffocation)
50 to 100 mA — possible ventricular fibrillation*
100 to 200 mA — certain ventricular fibrillation*
Over 200 mA — severe burns-muscle contractions

Ventricular fibrillation is defined as "very rapid uncoordinated contractions of the ventricles of the heart resulting in loss of synchronization between heart beat and pulse beat". Once ventricular fibrillation occurs in man, it usually continues and death will ensue within a few minutes.

GROUND FAULT PROTECTION FOR PEOPLE

Now, will a conventional overcurrent device open a circuit before irreparable harm is done? NO! Here's why.

The current that would flow from a defective electric drill, for example, through the metal housing and through the human body to ground would be 43 milliamperes, calculated using 2,800 ohms as average body resistance. Using 1,000 ohms as body resistance, the current flow would be 120 milliamperes.

43 milliamperes is only 0.29% of the current required to open a 15 ampere circuit breaker or fuse, and yet it approaches the current level which may produce ventricular fibrillation. Obviously, the standard circuit breaker or fuse will not open the circuit under such low levels of current flow.

By permission, Square D Schneider Electric, Greenville, WI.

10.5.2 How a GFCI Operates

GROUND FAULT CIRCUIT INTERRUPTERS (GFCI)

"People protector" devices are built as Class A devices in accordance with Underwriters Laboratories (UL) Standard No. 943 for Ground Fault Circuit Interrupters. UL defines a Class A device as one that "will trip when a fault current to ground is 6 milliamperes or more." the tripping time of such units cannot exceed the value obtained by the equation:

$$T=\left(\frac{20}{I}\right)^{1.43}$$

where T is time in seconds and **I** is the ground fault current in milliamperes. Also, Class A devices must not trip below 4 milliamperes.

Class A GFCI's include a self contained means of testing the ground fault circuitry, as required by UL. To test, simply push the test button and the device will respond with a trip indication. UL requires that the current generated by the test circuit shall not exceed 9 milliamperes. Also, UL requires the device to be functional at 85% of the rated voltage.



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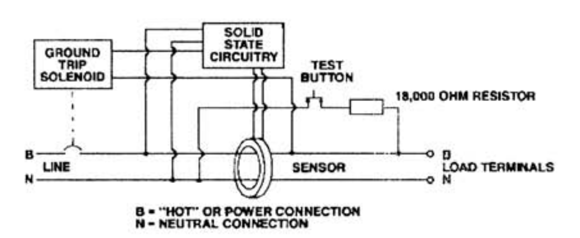
10.5.2 How a GFCI Operates (Continued)

GROUND FAULT PROTECTION FOR PEOPLE

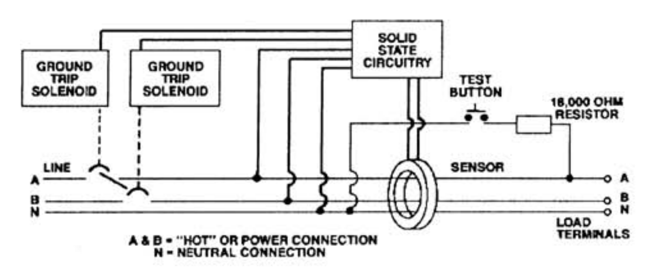
HOW THE GFCI OPERATES

The GFCI sensor in single pole QWIK-GARD circuit breakers continuously monitors the current balance in the ungrounded "hot" load conductor and the neutral load conductor. If the current in the neutral load wire becomes less than the current in the "hot" load wire, then a ground fault exists, since a portion of the current is returning to the source by some means other than the neutral load wire. When an imbalance in current occurs, the sensor sends a signal to the solid state circuitry which activates the ground trip solenoid mechanism and breaks the "hot" load connection. A current imbalance as low as 6 milliamperes will cause the circuit breaker to interrupt the circuit. This will be indicated by the VISI-TRIP indicator as well as the position of the operating handle centered between "OFF" and "ON".

Square D manufactures two types of GFCI devices: the QWIK-GARD circuit breaker and the plug-in QWIK-GARD receptacle.



SINGLE POLE QWIK-GARD BREAKER

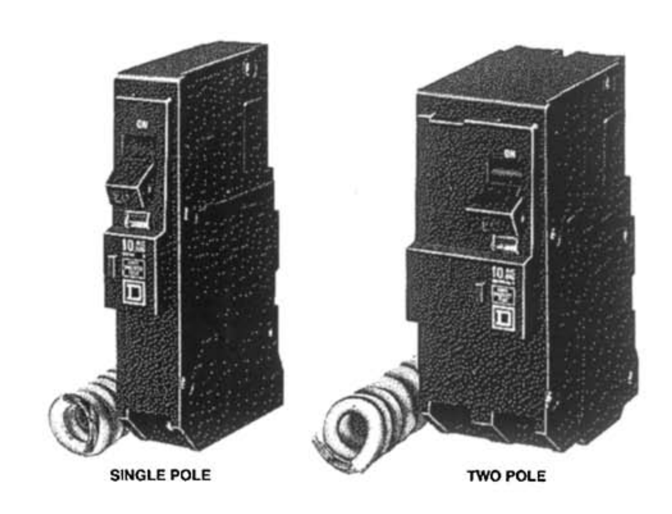


TWO POLE QWIK-GARD BREAKER

The two pole QWIK-GARD circuit breaker continuously monitors the current balance between the two "hot" conductors and the neutral conductor. If a neutral load conductor is not used, then the two pole QWIK-GARD circuit breaker continuously monitors the current balance between the two "hot" conductors. As long as the sum of the three or two currents is zero, the device will not trip; e.g., if there were 10 amperes current in the A load wire, 5 amperes in the neutral, and 5 amperes in the B load wire, then the sensor is balanced and will not produce a signal. A current imbalance from a ground fault condition as low as 6 milliamperes will cause the sensor to produce a signal of sufficient magnitude to trip the device.

QWIK-GARD CIRCUIT BREAKERS

QWIK-GARD circuit breakers require the same mounting space as standard QO circuit breakers and provide the same branch circuit wiring protection as standard QO circuit breakers. They also provide Class A ground fault protection.



SINGLE POLE TWO POLE

QWIK-GARD breakers are UL listed and available in both single and two pole construction. Single pole breakers are available in 15, 20, 25 and 30 ampere ratings and are available in 10,000 or 22,000 ampere interrupting capacity. Two pole breakers are available in 15, 20, 25, 30, 40, 50 and 60 ampere ratings and have a 10,000 ampere interrupting capacity. Single pole units are rated 120VAC and two pole units 120/240VAC.

QWIK-GARD circuit breakers not only can be used in Square D load centers and panelboards, but they are also available factory installed in HITCH-N-POST meter pedestals and SERVICEPAK power outlet panels for RV parks and construction sites.

SINGLE POLE QWIK-GARD CIRCUIT BREAKERS

The single pole breaker (Figure 1) has two load lugs and a white wire "pigtail" in addition to the line side plug-on or bolt-on connector. The line side "hot" connection is made by installing the QWIK-GARD breaker in the panel the same as you would install any QO or QOB circuit breaker.

10.5.2 How a GFCI Operates (Continued)

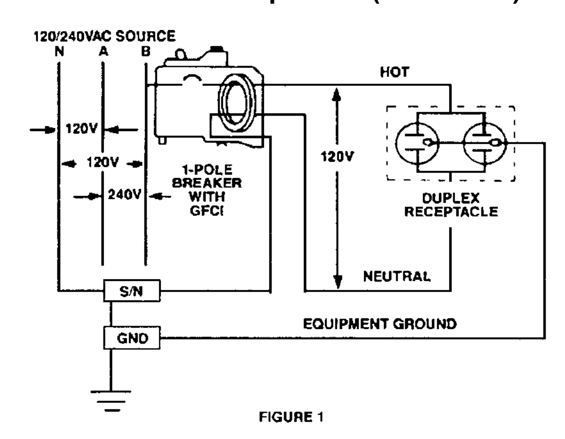


FIGURE 1

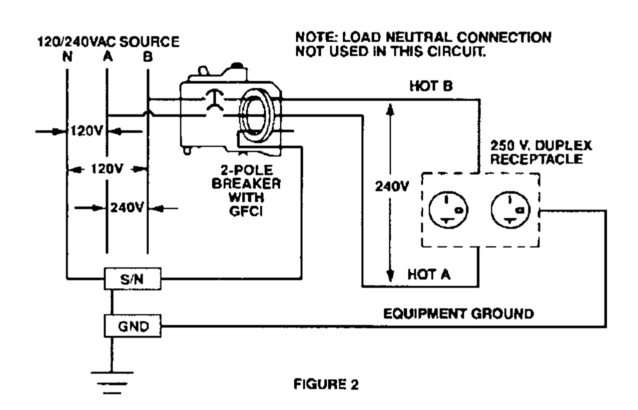


FIGURE 2

The white wire "pigtail" is connected to the panel neutral (S/N) assembly. Both the neutral and "hot" wires of the branch circuit being protected are terminated in the QWIK-GARD breaker. The two load lugs are clearly marked "LOAD POWER" and "LOAD NEUTRAL" by moldings in the breaker case. Also molded in the case is the identifying marking for the "pigtail", "PANEL NEUTRAL".

Single pole QWIK-GARD circuit breakers must be installed on independent circuits. Circuits which employ a neutral common to more than one "hot" conductor cannot be protected against ground faults by a single pole breaker because a common neutral cannot be split and retain the necessary "hot" wire-neutral wire balance under normal use to prevent the QWIK-GARD circuit breaker from tripping.

Care must be exercised when installing QWIK-GARD breakers in existing panels to be sure the neutral wire for the branch circuit corresponds with the "hot" wire of the same circuit.

Always remember that unless the current in the neutral wire is equal to that in the "hot" wire (within 6 milliamperes), the QWIK-GARD breaker senses this as being a ground fault.

TWO POLE QWIK-GARD CIRCUIT BREAKERS

A two pole QWIK-GARD circuit breaker can be installed on a 120/240VAC 1 phase 3 wire system, the 120/240VAC portion of the 120/240VAC 3 phase 4 wire system, or two phases and neutral of a 208Y/120VAC 3 phase 4 wire system. Regardless of the application, the installation of the breaker is the same — connections made to two "hot" busses and the panel neutral assembly. When installed on these systems, protection is provided for two wire 240VAC or 208VAC circuits (Figure 2); three wire 120/240VAC or 120/208VAC circuits (Figure 3) and 120VAC multi-wire circuits (Figure 4).

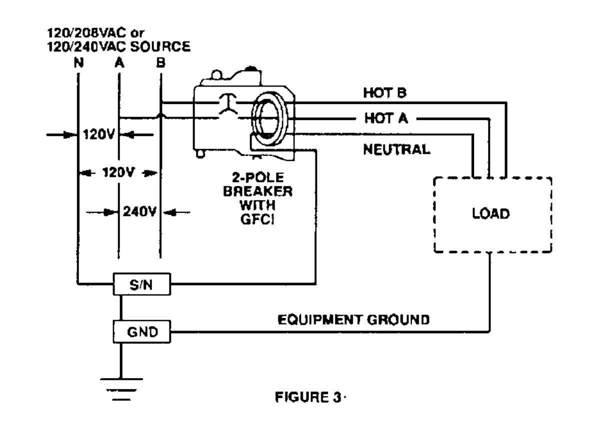


FIGURE 3

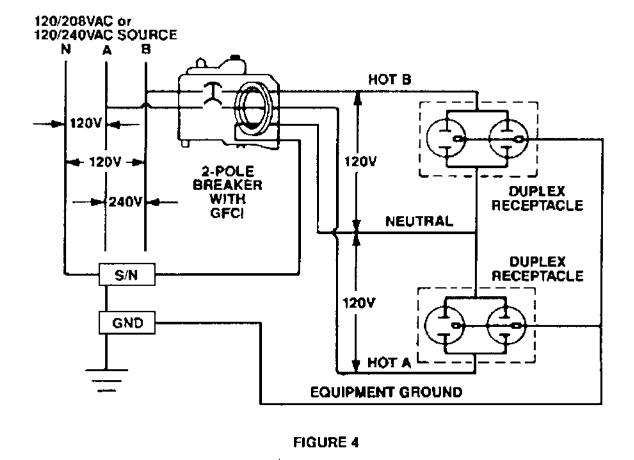


FIGURE 4

10.6.0 Low-Voltage Systems

The term *low voltage* has several definitions. As it relates to lighting, it often refers to 12-V power reduced from a 120-V source via a transformer. Another definition is any power source less than 250 V, as contrasted with high voltage. And last, low voltage can be defined as that voltage "deemed save for indoor usage," generally 120 V or less.

10.6.1 Low-Voltage Power Systems in both Single-Phase and Three-Phase

LOW VOLTAGE POWER SYSTEMS

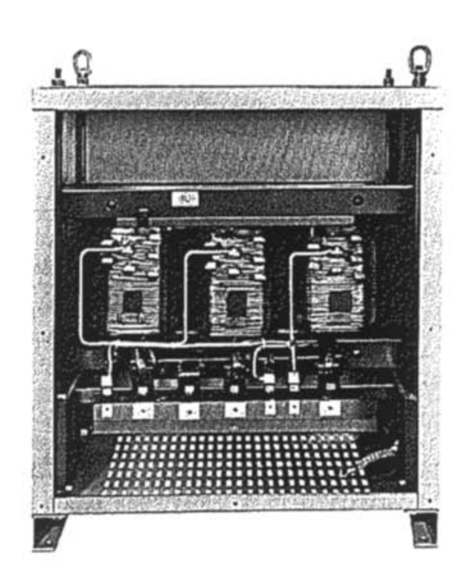
Voltage is the force that makes current flow from the generator, through the transmission lines, pass across transformers and ultimately reach the load where some kind of work is to be done. Voltage is one of the first ratings required when selecting electrical equipment. There are other ratings just as important, such as current, ambient temperature, frequency and interrupting capacity. For now, we will only study the voltage ratings as they pertain to low voltage power systems.

Voltage constantly changes in value. In some applications, it has to be regulated and made to stay at one value or at least very close to a chosen value. But with electricity as supplied to us from a utility and used in our everyday life, voltage will vary as loads are connected and disconnected from the system. Standard values of voltage have been established for the various systems. They are known as the "nominal" values of voltage. Nominal supply voltage ratings, as established by ANSI (American National Standards Institute), will be used throughout this book.

We will talk in terms of voltage as it appears at the secondary terminals of the transformer. Voltage at this point may be slightly different from that found at the load end of a wire and conduit run, but the nominal value will remain the same. Since we will be including transformers in our diagrams, maybe we should take a close look at them now.

TRANSFORMERS

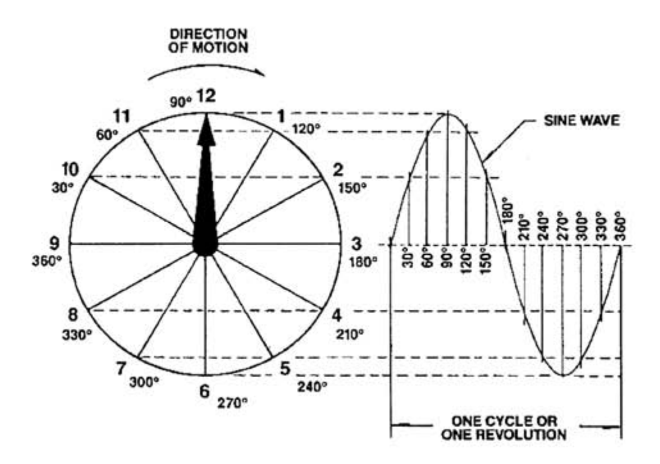
A transformer is defined as an electrical device, without moving parts that is capable of transferring electrical energy from one circuit to another. Transformers may be used to increase or decrease the voltage level on a system. They do not change the frequency of the system.



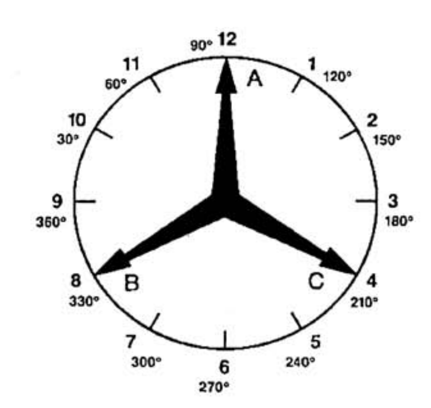
Transformers are constructed by winding two insulated coils of wire around a common steel core. One coil is connected to the electrical supply system. We call this the "primary" winding. The other is connected to the load circuit, and we call this the "secondary" winding. For simplicity, we'll only talk in terms of the secondary windings. More detailed information about transformers can be obtained from the SORGEL Dry-Type Transformer Study Course.

PHASE

Now let's try to understand "phase" as we are about to use it. A single phase system is much like a clock with only one hand. The voltage on a single phase system varies much like the clock's hand. Imagine a line drawn across the clock which passes through the three and nine o'clock positions. Each time the hand passes this line, picture the voltage as being zero. A curve, as traced by the moving hand, will pass through zero or across the line twice, with each complete revolution. This curve is similar to the varying voltage on a single phase sytem.

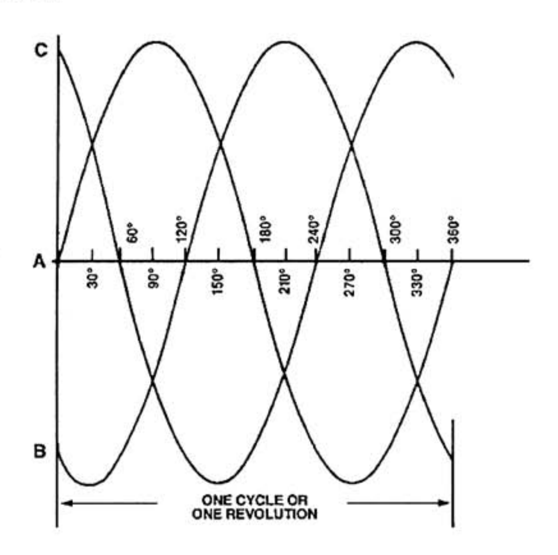


A three phase system may be pictured in a similar manner. In this case, the clock will have three hands mounted on a common shaft. The hands are equally spaced around the face. For example, at one instant a hand may be on



10.6.1 Low-Voltage Power Systems in Both Single-Phase and Three-Phase (Continued)

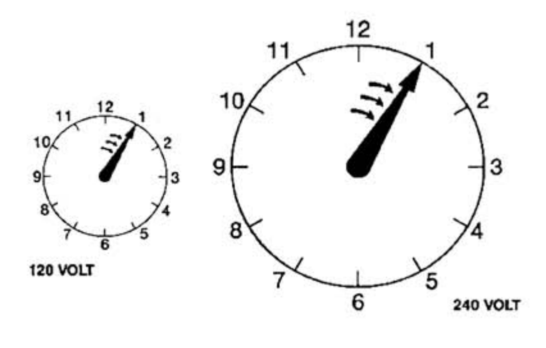
the twelve, another on the four and the third on the eight o'clock positions. Each hand will trace a separate curve and all three curves are being traced at the same time. Each hand will pass across the zero line twice during a complete revolution of the clock's face. These curves will be similar to the varying voltages on the three phase system.



"Phase," as we will use it, is the existence of the voltage curves on the systems. Single phase means there is only one voltage curve present, while three phase indicates that there are three voltage curves present on the system simultaneously.

VOLTAGE & FREQUENCY

The hands of the clock may also be imagined as depicting the value of voltage on the system. For example, a 120 volt single phase system could be represented by a two-inch hand, while a four-inch hand could represent a 240 volt single phase system. The speed of the hand traveling around the clock could represent the frequency of the system. We will be thinking in terms of 60 hertz systems normally, so the hands will be spinning around 60 times a second. At other frequencies, the hands will spin faster or slower.

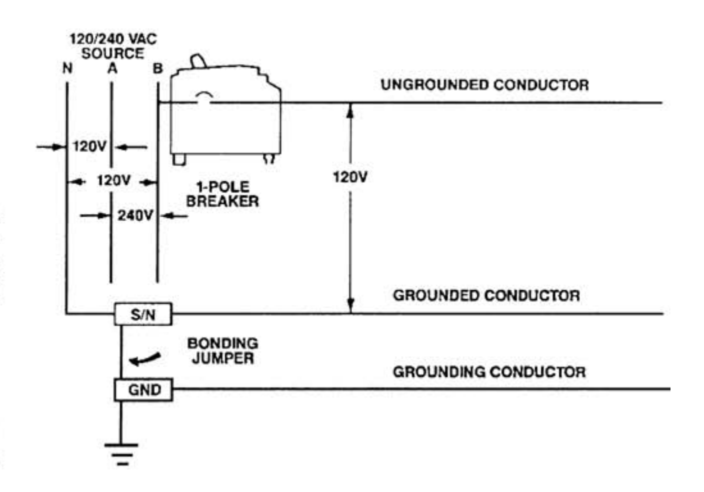


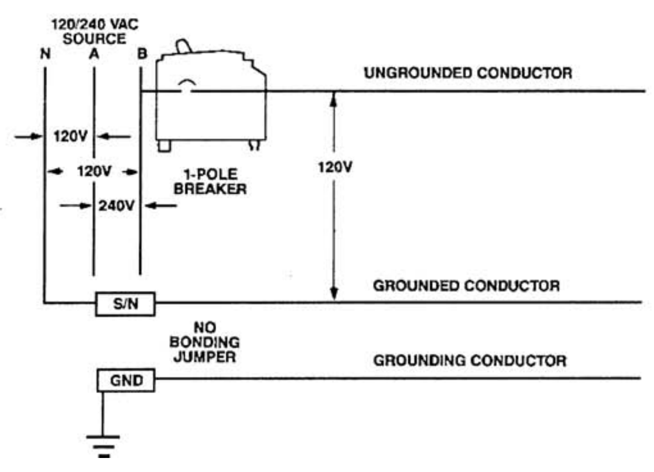
GROUNDING

One very important aspect of an electrical system is the method used for grounding. People handling and operating the equipment are normally considered to be at the same voltage level as the ground. So the grounding method, or lack of it, will determine how much insulation should be provided with the equipment and how hazardous may be the system.

Two methods for grounding are in use today. One method is external from the system and is used to protect people from electrical shocks while the other is internal to the system and is used to limit the available voltage level exposed to people. The first is called a "grounding" conductor and the latter is called a "grounded" conductor.

Grounding conductors may be green or bare wires, or could be the metal enclosures on a raceway housing the circuit conductors. In any case, grounding conductors are





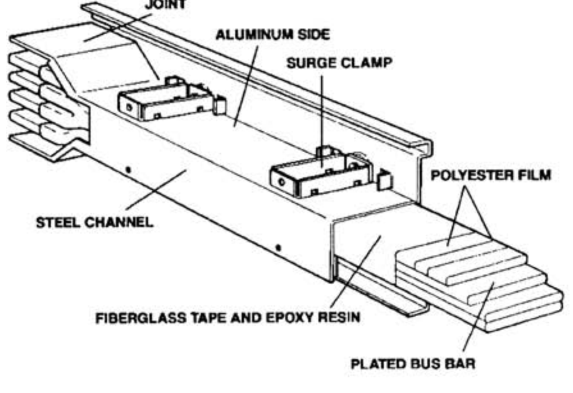
By permission, Square D Schneider Electric, Greenville, WI.

10.7.0 Busways

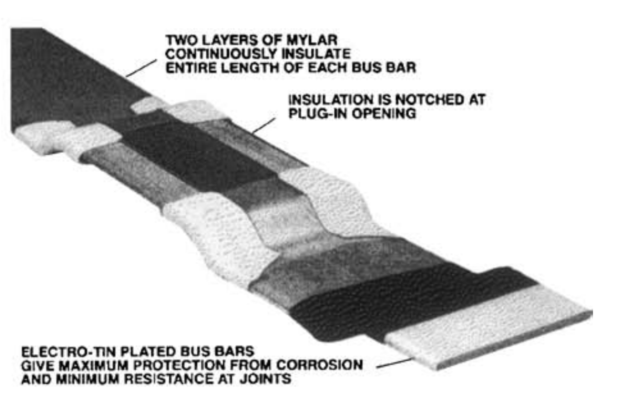
Busways are another way to distribute power in a factory, commercial, or institutional building. These large “bars” of coated aluminum or copper provide an electric feeder pathway that can be tapped into by either plug-in connections or direct connections.

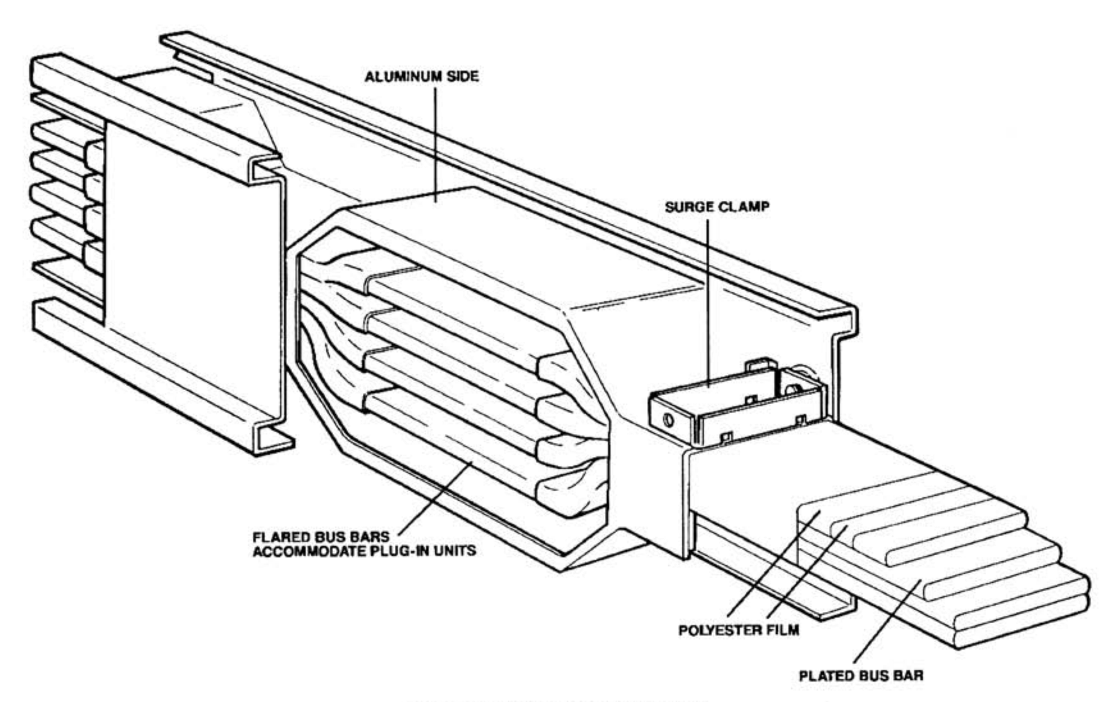
BUSWAY

Bus bars on both feeder and plug-in busway are insulated over the entire length of the bar. This is necessary to prevent the propagation of traveling arcs. Should there be, by some mischance, an arc formed between bus bars in I-LINE busway, it would be confined to one length and would not damge adjacent lengths. Furthermore, the fault would be a low impedance path because of the ionized air created at the arc. This would allow the overcurrent device protecting the run to operate rapidly, clearing the fault. Traveling arcs, common to non-insulated bus bars, create extensive damage because they run down the length of a busway and are a high impedance path for the fault current.



I-LINE II FEEDER BUSWAY CONSTRUCTION





I-LINE II PLUG-IN BUSWAY CONSTRUCTION

I-LINE is a Registered Trademark of Square D Company.
MYLAR is a Registered Trademark of DuPont.

By permission, Square D Schneider Electric, Greenville, WI.

10.7.0 Busways (Continued)

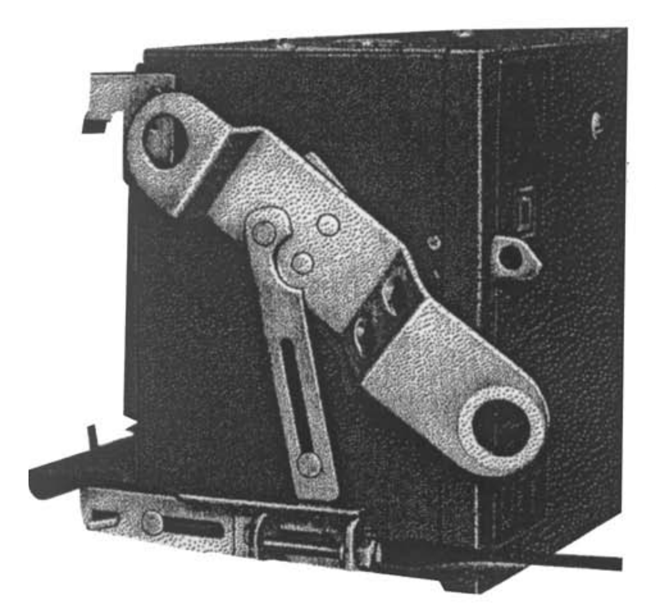
In the normal plugging in of the unit, most of the weight of the plug is transferred from the installer to the plug-in busway in the first operation. The installer can then check the "feel of the alignment" before rotating the unit into the seated position.

All plug-in units are provided with a saw tooth grounding spring which makes a positive 'static' ground connection between the plug body and the busway housing prior to jaw contact with the bus bars. An optional 'blow-on' style high ampere ground jaw is also available. To complete the installation on most units, it is only necessary to tighten a single clamping screw, which rigidly fastens the plug enclosure to the busway housing. Tightening this clamping screw also releases the interlock so that the switching mechanism may be operated.

The manner in which plug-in units are mounted polarizes the units so that the neutral is always the bottom conductor. High ampere bolt-on units are available for use with 800 ampere through 5000 ampere I-LINE plug-in busway. These units include most of the plug-in unit features listed above with the addition of the bolted type connection for high ampere or severe duty loads.

A full line of plug-in and bolt-on units is available, including:

1. Fusible units from 30 to 1600 amperes.
2. Circuit breaker units from 15 to 1600 amperes.
3. Combination starter and contactor units through NEMA size 3.
4. Transformer units through 10kVA.
5. Capacitor units through 30 kvar.
6. Ground detector units.



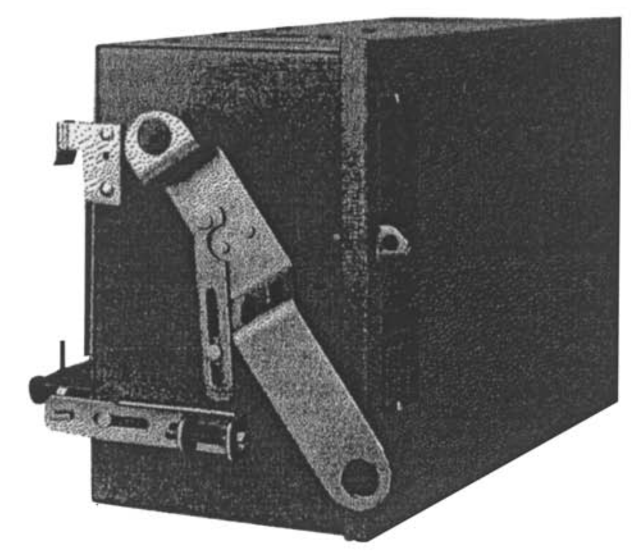
SWITCH INTERLOCK MECHANISM SHOWING CLAMPING SCREW BACKED OUT. PLUG-IN UNIT IS READY TO MOUNT

I-LINE is a Registered Trademark of Square D Company.
NEMA is a Registered Trademark of the National Electrical Manufacturers Association.
UL is a Registered Trademark of Underwriters Laboratories, Inc.

FUSIBLE UNITS

Fusible units through 400 amperes use the heavy duty safety switch mechanism. This switch mechanism is quick-make, quick-break, independent of the operating handle and incorporates visible blades, plated parts, arc suppressors and a one-piece crossbar.

Operation of this mechanism is such that it is not possible to restrain the main contacts once the operating handle has started the closing action. The switch has positive action, and may be opened or closed even if the main operating spring should be broken. All phase jaws are operated by the same solid one-piece crossbar.



FUSIBLE PLUG-IN UNIT

When the cover of the plug-in unit is open, the position and condition of the switch blades can be seen. There is no question as to whether the switch is "ON" or "OFF". Units may be positively padlocked in the "OFF" position. No live parts are exposed when the switch is off. The molded arc chamber barrier completely covers the line side terminals. Heavy duty switches equipped with UL Class RK9 (400 amperes and below) fuses have been tested satisfactorily on systems capable of delivering up to 100,000 symmetrical RMS amperes short circuit current. All switches withstood the tests without any signs of failure.

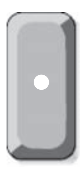
The operating handle is mounted on the end of the plug-in box, not on the cover, and is always in control of the switch (400 amperes and below). All plug-in units have interlocked doors. The door interlock can be overridden by use of a screwdriver so that the door can be opened while the switch is in the "ON" position.

Note that to remove the switch from the busway, the clamping screw must first be backed out. This insures that the unit is in the "OFF" position before being removed from the busway.

10.8.0 Cables, Wire, and Conduits

Electric cable equivalents, British Standard Wire Gauge cable (conductor) sizes are based on wire diameter; metric conductor sizes are based on the nominal area of the cross section of the cable; and American Wire Gauge sizes are based upon the nominal area of the cable's cross section.

10.9.0 Metric to American Wire Gauge (AWG) Cable



Metric to American Wire Gauge

The American Wire Gauge describes the wire's diameter; the metric conductor sizes describe the nominal area of the cross section of the conductor. The actual cross-sectional areas depend in part upon the stranding of the cable.

A cable with the AWG value shown will have at least as much carrying capacity as the metric cable for which it is being substituted. In other words, values have always been rounded down. For that reason, do not use this table to find the metric equivalent to an AWG cable. For that, go here.

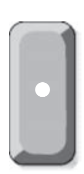
The table assumes substitution of an AWG-sized cable of the same type as the metric-sized cable. It cannot be used, for example, to find an AWG-sized aluminum cable to substitute for a copper metric cable. If the types are dissimilar, consult the cable manufacturer's literature to determine capacity.

Nominal Cross-sectional Area in square millimeters (the ISO standard)	Substitute this American Wire Gauge
0.5	20
0.75	18
1.0	16
1.5	14
2.5	12
4	10
6	9
10	7
16	5
25	3
35	1
50	0
70	3/0
95	4/0

Source: Sizes, Inc.

10.9.0.1 Metric to Standard Wire Gauge (SWG) Cable

Metric to Standard Wire Gauge



The British Standard Wire Gauge describes the wire's diameter; the metric conductor sizes describe the nominal areas of the cross section of the conductor. The actual cross-sectional areas depend in part upon the stranding of the cable.

A cable with the SWG value shown will have at least as much carrying capacity as the metric cable for which it is being substituted. In other words, values have always been rounded down. Some of the values shown, although the minimum size needed, are not commercially available. In that case, use the next heavier available size.

Do not use this table to find the metric equivalent to an SWG cable. For that, go here.

The table assumes substitution of an SWG-sized cable of the same type as the metric-sized cable. It cannot be used, for example, to find an SWG-sized aluminum cable to substitute for a copper metric cable. If the types are dissimilar, consult the cable manufacture's literature to determine capacity.

Nominal Cross-sectional Area in square millimeters (the ISO standard)	Substitute this Standard wire Gauge
0.5	21
0.75	19
1.0	18
1.5	17
2.5	15
4	13
0	70
1	50
2	50
3	35
4	35
5	25
6	25
7	16
8	16
9	16
10	10
11	10
12	6
13	6
14	4
15	4
16	2.5
17	2.5
18	1.5
19	1
20	0.75
21	0.75
22	0.5

Source: Sizes, Inc.

10.9.1 Rigid Conduit Dimensions and Knockout Size

Both rigid conduit and intermediate metallic conduit are threaded and accept couplings, nuts, and bushings et cetera directly.

ALL SIZES ARE INCHES		INSIDE DIAMETER (ID)	OUTSIDE DIAMETER (OD)		KNOCKOUT SIZE
TRADE SIZE	THREADS PER INCH	**NOMINAL** (1)	**NOMINAL**	MAXIMUM (2)	**NOMINAL** (3)
1/4	18	**.364**	**.540**	-	**.575**
3/8	18	**.493**	**.675**	-	**.718**
1/2	14	**.632**	**.840**	.855	**.875**
3/4	14	**.836**	**1.050**	1.066	**1.109**
1	11-1/2	**1.063**	**1.315**	1.331	**1.375**
1-1/4	11-1/2	**1.394**	**1.660**	1.676	**1.734**
1-1/2	11-1/2	**1.624**	**1.900**	1.916	**1.984**
2	11-1/2	**2.083**	**2.375**	2.399	**2.469**
2-1/2	8	**2.489**	**2.875**	2.904	**2.969**
3	8	**3.090**	**3.500**	3.535	**3.594**
3-1/2	8	**3.570**	**4.000**	4.040	**4.123**
4	8	**4.050**	**4.500**	4.545	**4.641**
4-1/2	8	**4.506**	**5.000**	5.050	**5.109**
5	8	**5.073**	**5.563**	5.619	**5.719**
6	8	**6.093**	**6.625**	6.691	**6.813**

(1)U.L. Table NAE.3.
(2)Maximum Outside Diameter Per ANSI C80.1-1977.
(3)Dimensions for trade sizes of 1/4 through 1-1/4 are from Table 20.2 of ANSI/UL 514-1978.
Sizes 1/ 2 " thru 6" per proposed revision to NEMA Engineering Bulletin No. 71, Aug. 1976.

Source: home4c.com.

10.9.2 Electrical Metallic Tubing (EMT), Inside/Outside Dimensions and Wall Thickness

Electrical metallic tubing is not threaded, and must be connected to junction boxes and the like with conduit connectors that secure to the tubing by means of a set screw or collet and nut; then the connectors have integrated shoulders and threads that secure to the box with a nut.

ALL SIZES ARE INCHES	INSIDE DIAMETER (ID)	WALL THICKNESS	OUTSIDE DIAMETER (OD)	
TRADE SIZE	**NOMINAL**	NOMINAL	**NOMINAL**	TOLERANCE
3/8	**.493**	.042	**.577**	+/- .005
1/2	**.622**	.042	**.706**	+/-.005
3/4	**.824**	.049	**.922**	+/-.005
1	**1.049**	.057	**1.163**	+/-.005
1-1/4	**1.380**	.065	**1.510**	+/-.005
1-1/2	**1.610**	.065	**1.740**	+/-.005
2	**2.067**	.065	**2.197**	+/-.005
2-1/2	**2.731**	.072	**2.875**	+/-.010
3	**3.356**	.072	**3.500**	+/-.015
3-1/2	**3.834**	.083	**4.000**	+/-.020

Source: home4c.com.

10.9.3 Intermediate Metallic Conduit (IMC), Inside/Outside Dimensions

INTERMEDIATE METALLIC CONDUIT (IMC)

ALL SIZES ARE INCHES		INSIDE DIAMETER (ID)	OUTSIDE DIAMETER (OD)	
TRADE SIZE	THREADS PER INCH	**NOMINAL**	**NOMINAL**	MAXIMUM
1/2	14	**.675**	**.815**	.820
3/4	14	**.879**	**1.029**	1.034
1	11-1/2	**1.120**	**1.290**	1.295
1-1/4	11-1/2	**1.468**	**1.638**	1.645
1-1/2	11-1/2	**1.703**	**1.883**	1.890
2	11-1/2	**2.170**	**2.360**	2.367
2-1/2	8	**2.597**	**2.857**	2.867
3	8	**3.216**	**3.476**	3.486
3-1/2	8	**3.711**	**3.971**	3.981
4	8	**4.206**	**4.466**	4.476

U.L. Proposed Dimensions for Intermediate Metallic Conduit - Type I.
IMC Threads and Knockout Sizes are the same as Rigid Metal Conduit.
Standard rigid threaded conduit fittings can be used with I.M.C.

Source: home4c.com.

10.9.4 Plastic Conduit Bushing Sizes

ALL SIZES ARE INCHES	TRADE SIZE	DIMENSION A	DIMENSION B
	1/2	**1.050**	**.365**
	3/4	**1.280**	**.390**
	1	**1.632**	**.490**
	1-1/4	**1.986**	**.535**
	1-1/2	**2.160**	**.550**
	2	**2.680**	**.600**
	2-1/2	**3.150**	**.635**
	3	**3.800**	**.725**
	3-1/2	**4.275**	**.725**
	4	**4.775**	**.750**
	5	**6.350**	**.975**
	6	**7.475**	**.975**

Source: home4c.com.

10.10.0 Maximum Allowable Diameter of Individual Cables in Conduit

Maximum allowable diameter (in inches) of individual cables in given size of conduit				
Non-metallic jacketed cable — all cables of same outside diameter				
Nominal size conduit	Number of cables having same O.D.			
	1	2	3	4
..1/2	0.453	0.244	0.227	0.197
..3/4	0.600	0.324	0.301	0.260
..1	0.763	0.412	0.383	0.332
..1 1/4	1.010	0.542	0.504	0.436
..1 1/2	1.173	0.633	0.588	0.509
..2	1.505	0.812	0.754	0.653
..2 1/2	1.797	0.970	0.901	0.780
..3	2.234	1.206	1.120	0.970
..3 1/2	2.583	1.395	1.296	1.121
..4	2.930	1.583	1.470	1.273
..5	3.675	1.985	1.844	1.595
..6	4.416	2.385	2.215	1.916

Source: The Okonite Company.

10.10.1 Number of Conductors for Various Size Ducts

CONDUCTOR TABLE
NO DERATING NECESSARY UP TO CONDUCTORS OR 20% FILL — NEC 362-5

Conductor Size	Area of Conductor (In²)		Maximum Number of Conductors All of One Size at 20% Fill									
	Type T TW THW	Type THHN THWN XHHW	2½"x2½" Duct ‡1.25 in²		4"x4" Duct ‡3.2 in²		6"x6" Duct ‡7.2 in²		8"x8" Duct ‡12.8 in²		12"x12" Duct ‡28.8 in²	
	A	B	A	B	A	B	A	B	A	B	A	B
14	.0135	.008	*92	*143	*237	*368	*533	*827	*950	*1471	*2133	*3310
12	.0172	.0117	*72	*107	*186	*273	*428	*615	*744	*1094	*1674	*2461
10	.0224	.0184	*55	* 68	*142	*174	*321	*391	*570	* 695	*1285	*1565
8	.0471	.0373	26	* 33	* 68	* 85	*153	*193	*271	* 343	* 611	* 722
6	.0819	.0519	15	24	* 39	* 61	* 87	*138	*156	* 246	* 351	* 555
4	.1087	.0845	11	14	29	* 38	* 66	* 85	*117	* 151	* 264	* 341
3	.1263	.0995	9	12	25	* 32	* 57	* 72	*101	* 128	* 228	* 289
2	.1473	.1182	8	10	21	27	* 46	* 61	* 87	* 108	* 195	* 243
1	.2027	.1590	6	8	15	20	* 35	* 45	* 63	* 80	* 142	* 181
0	.2367	.1893	5	6	13	17	20	* 38	* 54	* 67	* 121	* 152
00	.2781	.2265	4	5	11	14	25	* 31	* 46	* 56	* 103	* 127
000	.3288	.2715	3	4	9	11	21	26	* 39	* 47	* 87	* 106
0000	.3904	.3278	3	4	8	9	18	22	* 32	* 39	* 73	* 88
250MCM	.4877	.4026	2	3	6	8	14	18	26	* 31	* 59	* 71
300MCM	.5581	.4669	2	2	5	7	12	15	22	27	* 51	* 61
350MCM	.6291	.5307	2	2	5	6	11	13	20	24	* 45	* 54
400MCM	.6969	.5931	1	2	4	5	10	12	18	21	* 41	* 48
500MCM	.8316	.7163	1	1	4	4	8	10	15	18	* 34	* 40
600MCM	1.0261	.8792	1	1	3	3	7	8	12	14	* 28	* 32
700MCM	1.1575	1.0011	1	1	2	3	6	7	11	12	* 24	28
750MCM	1.2252	1.0623	1	1	2	3	5	6	10	12	23	27

* NOTE: The 1987 National Electrical Code limits installation to 30 conductors in one wireway except where derated according to table 310-16 through 310-18 NEC, or where special permission has been obtained from local authority enforcing the Code or where conductors in excess of 30 are for signalling circuits or are control wires between a motor and its starter and used only for starting duty, and other exceptions are noted in 520-5 (theaters), 620-32 (elevators), and 374-5 (auxiliary gutters).

† Areas for Type XHHW are .0131, .0167, .0456, and .0625 for sizes 14, 12, 10, 8, and 6 respectively.

• Areas for Type THW are .0206, .0251, .0311, and 0.598 for sizes 14, 12, 10, and 8 respectively.

‡ These values represent 20% of the interior cross-sectional area of the various sizes of the wireway.

Source: Sizes, Inc.

10.11.0 Jacket Materials Guide for Conductors

Jacket materials selection chart
Relative performance data

Mechanical	PVC	Polyethylene	Neoprene	Chlorosulphonated Polyethylene	Thermoplastic CPE
Abrasion Resistance	Good	Excellent	Good	Good	Excellent
Tensile Strength	Excellent	Excellent	Excellent	Excellent	Good
Elongation	Good	Excellent	Excellent	Excellent	Good
Compression Resistance	Good	Excellent	Excellent	Excellent	Good
Flexibility	Good	Fair	Excellent	Excellent	Fair
Environmental					
Flame	Good	Poor	Excellent	Excellent	Good
Moisture					
Fresh or salt water	Good	Exceptional	Good	Excellent	Excellent
Petroleum oils					
Motor oil		Excellent			Good
Fuel oil	Good	(Slight swelling	Good	Good	(Poor above 110°C)
Crude oil		above 60°C)			
Creosote	Poor	Good	Fair	Fair	Good
Paraffinic Hydrocarbons					
Gasoline	Good	Excellent	Poor	Poor	Excellent
Kerosene		(Slight swelling at			(Slight swelling at
Alcohols		higher temperatures)			higher temperatures)
Isopropyl					
Wood	Fair	Good	Fair	Good	Good
Grain					
Mineral Acids					
Sulfuric					
Nitric	Excellent	Excellent	Excellent	Excellent	Excellent
Hydrochloric					
Fixed Alkalis Sodium hydroxide (lye)					
Potassium hydroxide (potash)					
Calcium hydroxide (lime)	Good	Excellent	Good	Excellent	Excellent
Ketones					
Acetone					
Methyl ethyl ketone (MEK)	Poor	Good	Poor	Fair	Good
Esters					
Ethyl Acetate					
Most lacquer thinners	Poor	Good	Poor	Fair	Good
Halogenated Hydrocarbons					
Chloroform					
Carbon Tetrachloride					
Methyl Chloride	Poor	Poor	Poor	Poor	Poor
General					
Leaves protective residue after combustion	Yes	No	Yes	Yes	Yes
Oxygen Index (ASTM D-2863)	23-30%	17-18%	31-39%	30-36%	30-34%
Halogen content - % Wt.	26	0	18	14	18-20
Minimum installation temperature	14°F (-10°C)	-40°F (-40°C)	-4°F (-20°C)	-4°F (-20°C)	-40°F (-40°C)
Dimensional stability under hear	Fair	Fair	Excellent	Excellent	Fair
Maximum operating temperature	75°C (167°F)	75°C (167°F)	90°C (194°F)	90°C (194°F)	75°C (167°F)

Note: When cables are to be installed in cold weather, they should be kept in heated storage for at least 24 hrs. before installation.

Source: The Okonite Company.

10.12.0 Alternate Sources of Electricity

Alternate sources of electricity, other than fossil fuels and nuclear power, incorporate the power of the sun, wind, and water.

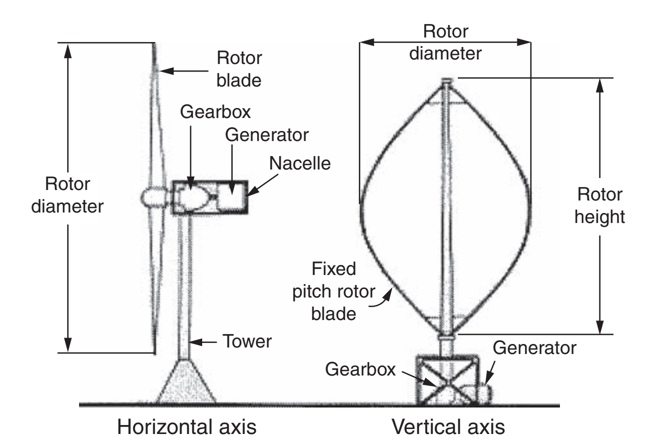
10.12.1 Solar Power

Solar power can be utilized by employing photovoltaic cells that absorb sunlight and then transfer this energy to a semiconductor. The ensuing flow of electrons generates electric current. Solar power can also be utilized as a heat source generating radiation to heat liquid in pipes that can create steam and drive a turbine generator.

10.12.2 Wind Turbines

Wind turbines connected to generators produce electricity and are configured in two shapes—horizontal axis (the more familiar type) and vertical axis—similar to an eggbeater.

There are two basic designs of wind electric turbines: vertical-axis, or "egg-beater" style, and horizontal-axis (propeller-style) machines. Horizontal-axis wind turbines are most common today.



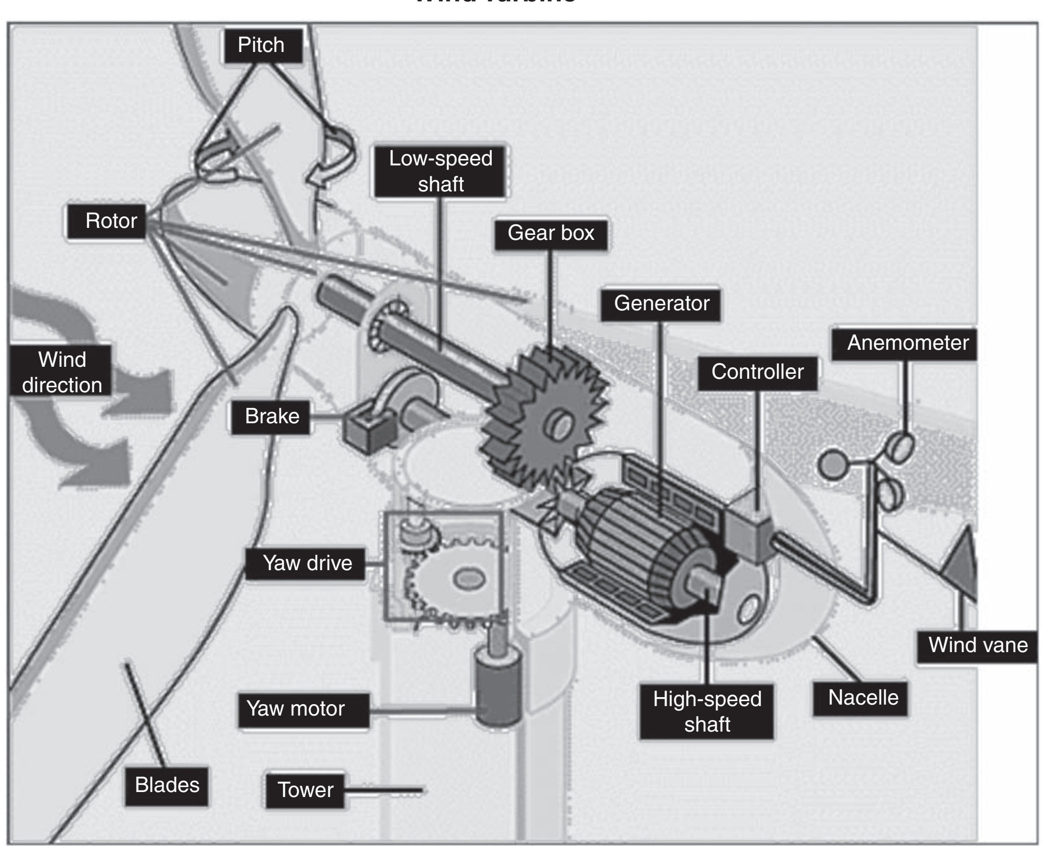
Wind turbine configurations

Turbine subsystems include:

- a rotor, or blades, which convert the wind's energy into rotational shaft energy;
- a nacelle (enclosure) containing a drive train, usually including a gearbox* and a generator;
- a tower, to support the rotor and drive train; and
- electronic equipment such as controls, electrical cables, ground support equipment, and interconnection equipment.

10.12.2.1 Inside a Wind Turbine

Wind Turbine



Source: U.S. Department of Energy.

10.12.2.2 Diagram of a Wind Turbine Connected to a Local Power Grid

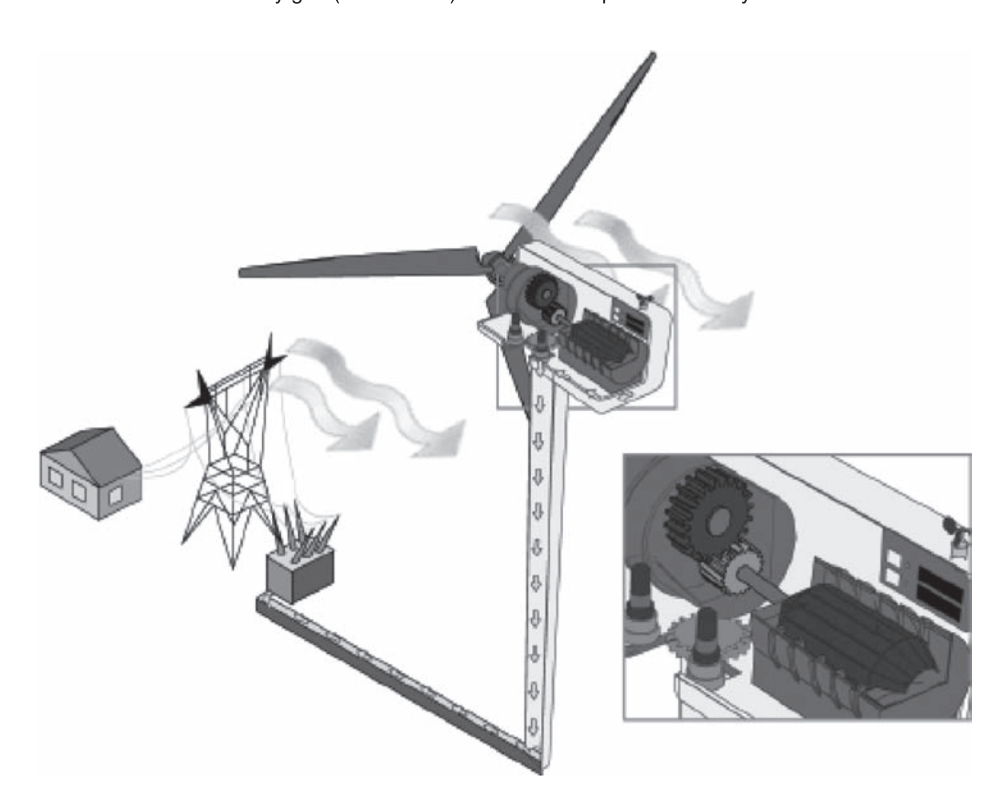
U.S. Department of Energy - Energy Efficiency and Renewable Energy
Wind and Hydropower Technologies Program

How Does a Wind Turbine Work?

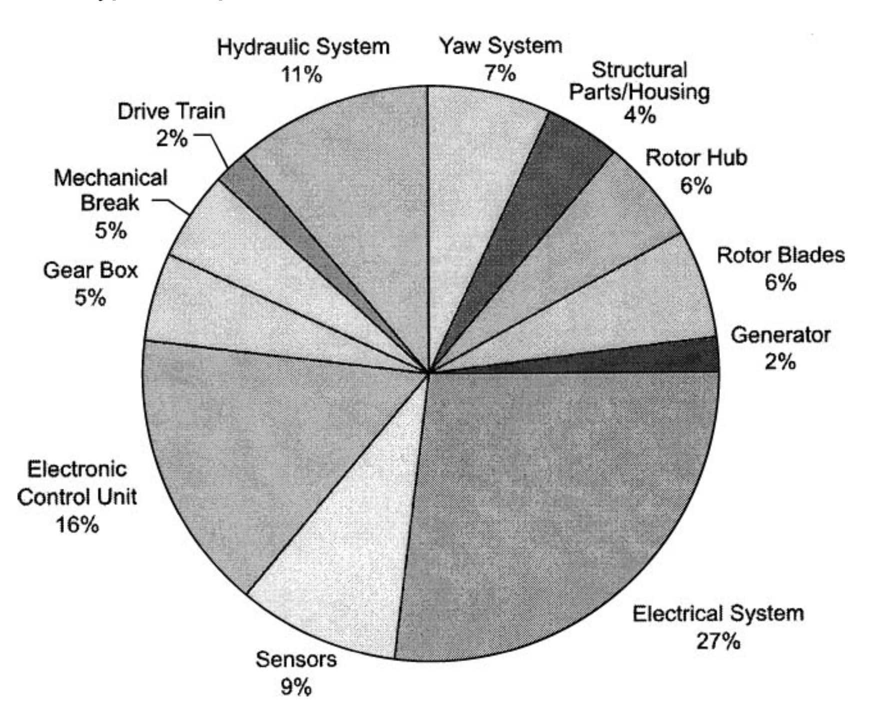
Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.

Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind.

Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid (shown here) for more widespread electricity distribution.



10.12.2.3 Types and Frequency of Repairs on Wind Turbine Components



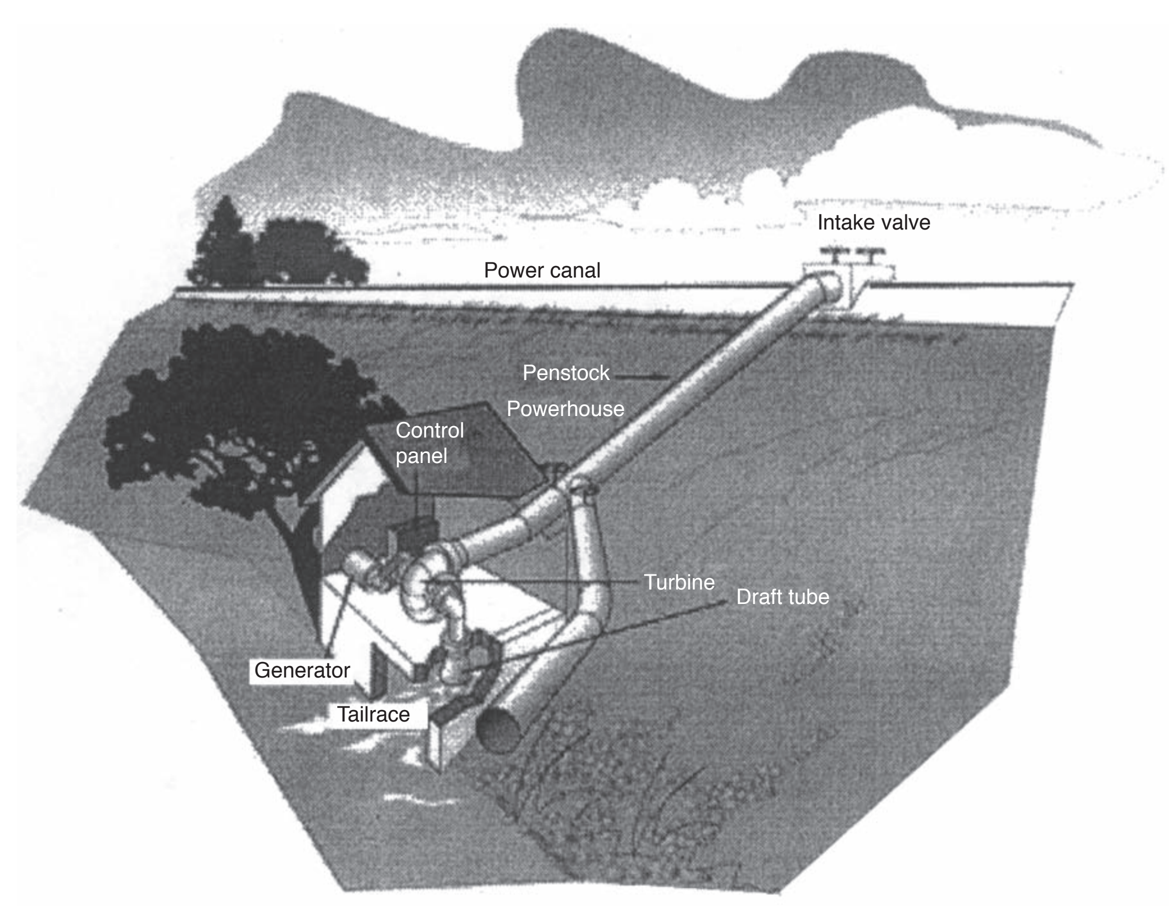
Source: U.S. Department of Energy.

10.12.3 Water Used to Generate Power

Water can be used to generate power in a number of ways, by tapping into water stored behind a dam, use of wave energy, or draining water from an elevated source.

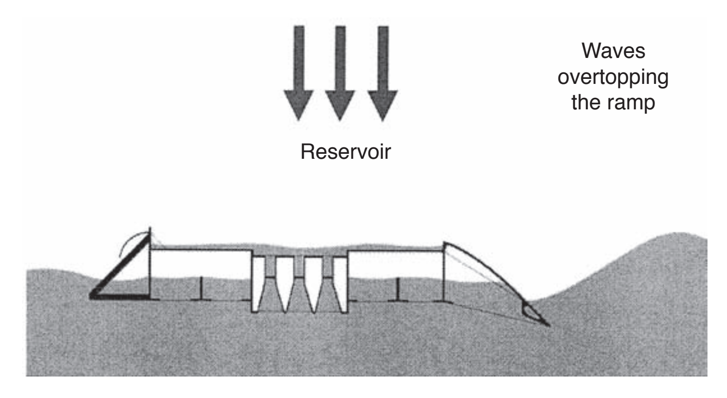
10.12.3(a) Draining Water from an Elevated Source

Water can be drained from a river or lake to turn a turbine and generate power.



Source: Idaho National Laboratory.

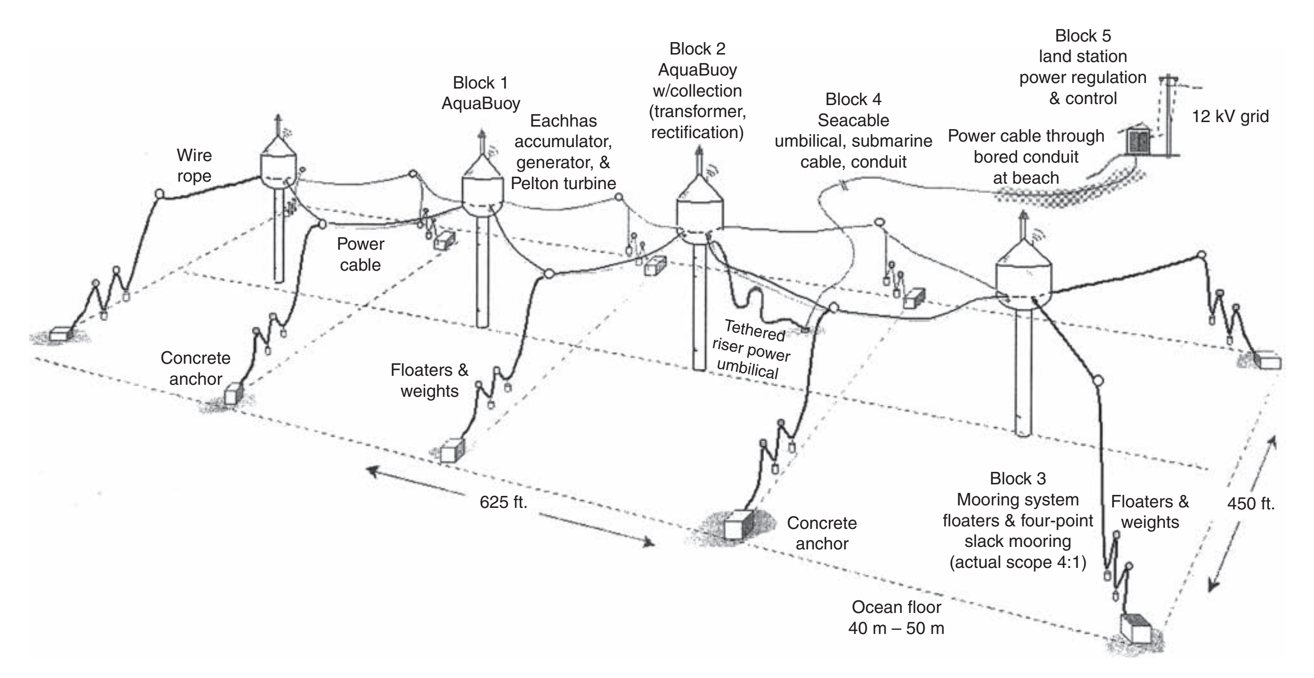
10.12.3(b) Tapping into Water Overflowing from a Reservoir



Source: U.S. Department of Energy.

10.12.3(c) Wave Energy

Wave energy moving against a series of buoys can generate electric current that can be transferred to an onshore generating source.



Source: AquaEnergy Group Ltd.

10.13.0 Energy Cost Calculator for Water-Cooled Electric Chillers

Vary equipment size, energy cost, hours of operation, and /or efficiency level.		
INPUT SECTION		
Input the following data (if any parameter is missing, calculator will set it to the default value).		*Defaults*
Chiller Project Type	New Installation	*New*
Existing Efficiency * Full Load	kW/ton	—
Existing Capacity *	tons	—
New Chiller Type (by compressor type)	Centrifugal	*Centrifugal*
New Capacity	tons	*500 tons*
New Efficiency Full Load	kW/ton	*0.56 kW/ton*
Energy Cost	$ per kWh	*$0.06 per kWh*
Quantity of Chillers to be Purchased	unit(s)	*1 unit*
Annual Hours of Operation**	hours	*2000 hours*

* Existing values should only be entered when Project Type is a replacement.
** Value entered should be equivalent full load hours (e.g., 1000 hours @ 50% load equals 500 hours.)

Calculate Reset

OUTPUT SECTION

Water-Cooled Chiller Performance	Your New Chiller	Existing Chiller	Base Model	FEMP Recommended Level	Best Available
Efficiency	kW/ton				
Annual Energy Use	kWh				
Annual Energy Cost	$	$	$	$	$
Lifetime Energy Cost	$	$	$	$	$
Lifetime Energy Cost Savings	$	$	$	$	$
Lifetime Energy Cost Savings for Chiller(s)	$	$	$	$	$

Your selection of a ton chiller unit will have a $ energy cost savings per chiller (over its estimated 23 year life expectancy compared to the base model).

Source: U.S. Department of Energy.

10.13.0 Energy Cost Calculator for Water-Cooled Electric Chillers (Continued)

Assumptions

- "Base model" has an efficiency that just meets ASHRAE Standard 90.1.
- Calculator assumes user is entering efficiency ratings based on ARI's 1998 Standard 550/590.
- Lifetime energy cost is the sum of the discounted value of the annual energy cost based on assumed chiller life of 23 years.
- Future electricity price trends and a discount rate of 3.2% are based on Federal guidelines.
- $0.06 for electricity is the Federal average price in the U.S.

Disclaimer

This cost calculator is a screening tool that estimates a product's lifetime energy cost savings at various efficiency levels. Maintenance and installation costs do not vary significantly among the same product having different efficiencies; so, these costs are not included in this calculator tool. For a detailed life-cycle cost analysis, FEMP has developed a tool called Building Life-Cycle Cost (BLCC). This downloadable tool allows the user to vary interest rates, installation costs, maintenance costs, salvage values, and life expectancy for a product or an entire energy project.

Existing Efficiency. Existing values should only be entered when Project Type is a replacement. Existing Capacity in tons. Existing values should only be entered when Project Type is a replacement. New Capacity in tons. Default is 500 tons New Efficiency in kilowatts per ton. Default is 0.56 kW/ton Energy cost per kilowatt hour. Default is $0.06 per kWh Quantity of Chillers to be Purchased in unit(s). Default is 1 unit Annual Hours of Operation in hours. Value entered should be equivalent full load hours (e.g., 1000 hours @ 50% load equals 500 hours.) Default is 2000 hours Efficiency of your new chiller in kilowatts per ton. Efficiency of your existing chiller. Efficiency of base model. FEMP recommended level of efficiency. Best available level of efficiency. Annual energy use of your new chiller in kilowatt hours. Annual energy use of your existing chiller in kilowatt hours. Annual energy use of base model. FEMP recommended level of annual energy use. Best available level of annual energy use. Annual energy cost of your new chiller in kilowatt hours. Annual energy cost of your existing chiller in kilowatt hours. Annual energy cost of base model. FEMP recommended level of annual energy cost. Best available level of annual energy cost. Lifetime energy cost of your new chiller in kilowatt hours. Lifetime energy cost of your existing chiller in kilowatt hours. Lifetime energy cost of base model. FEMP recommended level of lifetime energy cost. Best available level of lifetime energy cost. Lifetime energy cost savings of your new chiller in kilowatt hours. Lifetime energy cost savings of your existing chiller in kilowatt hours. Lifetime energy cost savings of base model. FEMP recommended level of lifetime energy cost savings. Best available level of lifetime energy cost savings. Lifetime energy cost savings of quantity of chiller(s). Lifetime energy cost savings of quantity of chiller(s) of your new chiller in kilowatt hours. Lifetime energy cost savings of quantity of chiller(s) of your existing chiller in kilowatt hours. Lifetime energy cost savings of quantity of chiller(s) of base model. FEMP recommended level of lifetime energy cost savings quantity of chiller(s). Best available level of lifetime energy cost savings quantity of chiller(s). Your selection of a ton chiller unit will have a energy cost savings per chiller (over its estimated 23 year life expectancy compared to the base model).

Source: U.S. Department of Energy.

10.13.1 Energy Cost Calculator for Air-Cooled Electric Chillers

Vary equipment size, energy cost, hours of operation, and /or efficiency level.		
INPUT SECTION		
Input the following data (if any parameter is missing, calculator will set it to the default value).		*Defaults*
Chiller Project Type	New Installation	*new*
Existing Efficiency * Full Load	kW/ton	—
Existing Capacity *	tons	—
New Chiller Type (by compressor type)	Screw	*screw*
New Capacity	tons	*100 tons*
New Efficiency Full Load	kW/ton	*1.23 kW/ton at Full Load*
Energy Cost	$ per kWh	*$0.06 per kWh*
Quantity of Chillers to be Purchased	unit(s)	*1 unit*
Annual Hours of Operation**	hours	*2000 hours*

* Existing values should only be entered when Project Type is a replacement.
** Value entered should be equivalent full load hours (e.g., 1000 hours @ 50% load equals 500 hours.)

Calculate Reset

OUTPUT SECTION

Air-Cooled Chiller Performance	Your New Chiller	Existing Chiller	Base Model	FEMP Recommended Level	Best Available
Efficiency	kW/ton				
Annual Energy Use	kWh				
Annual Energy Cost	$	$	$	$	$
Lifetime Energy Cost	$	$	$	$	$
Lifetime Energy Cost Savings	$	$	$	$	$
Lifetime Energy Cost Savings for Chiller(s)	$	$	$	$	$

Your selection of a ton chiller unit will have a $ energy cost savings per chiller (over its estimated 23 year life expectancy compared to the base model).

Source: U.S. Department of Energy.

10.13.1 Energy Cost Calculator for Air-Cooled Electric Chillers (Continued)

Assumptions

- "Base model" has an efficiency that just meets ASHRAE Standard 90.1.
- Calculator assumes user is entering efficiency ratings based on ARI's 1998 Standard 550/590.
- Lifetime energy cost is the sum of the discounted value of the annual energy cost based on assumed chiller life of 23 years.
- Future electricity price trends and a discount rate of 3.2% are based on Federal guidelines.
- $0.06 for electricity is the Federal average price in the U.S.

Disclaimer

This cost calculator is a screening tool that estimates a product's lifetime energy cost savings at various efficiency levels. Maintenance and installation costs do not vary significantly among the same product having different efficiencies; so, these costs are not included in this calculator tool. For a detailed life-cycle cost analysis, FEMP has developed a tool called Building Life-Cycle Cost (BLCC). This downloadable tool allows the user to vary interest rates, installation costs, maintenance costs, salvage values, and life expectancy for a product or an entire energy project.

Chiller Project Type Existing Efficiency Existing Efficiency in kilowatts per ton. Existing Capacity in tons. Existing values should only be entered when Project Type is a replacement. New Chiller Type (by compressor type) New capacity in tons. Default is 100. New efficiency New efficiency in kilowatts per ton. Default 1.23 kW/ton at Full Load Energy Cost per kilowatt hour. Default is 6 cents. Quantity of Chillers to be Purchased in units. Default is 1. Annual Hours of Operation. Value entered should be equivalent full load hours (e.g., 1000 hours @ 50% load equals 500 hours. Default is 2000.) Efficiency of your new chiller in kilowatts per ton. Efficiency of your existing chiller. Efficiency of base model. FEMP recommended level of efficiency. Best available level of efficiency. Annual energy use of your new chiller in kilowatt hours. Annual energy use of your existing chiller in kilowatt hours. Annual energy use of base model. FEMP recommended level of annual energy use. Best available level of annual energy use. Annual energy cost of your new chiller in kilowatt hours. Annual energy cost of your existing chiller in kilowatt hours. Annual energy cost of base model. FEMP recommended level of annual energy cost. Best available level of annual energy cost. Lifetime energy cost of your new chiller in kilowatt hours. Lifetime energy cost of your existing chiller in kilowatt hours. Lifetime energy cost of base model. FEMP recommended level of lifetime energy cost. Best available level of lifetime energy cost. Lifetime energy cost savings of your new chiller in kilowatt hours. Lifetime energy cost savings of your existing chiller in kilowatt hours. Lifetime energy cost savings of base model. FEMP recommended level of lifetime energy cost savings. Best available level of lifetime energy cost savings. Lifetime energy cost savings of quantity of chiller(s). Lifetime energy cost savings of quantity of chiller(s) of your new chiller in kilowatt hours. Lifetime energy cost savings of quantity of chiller(s) of your existing chiller in kilowatt hours. Lifetime energy cost savings of quantity of chiller(s) of base model. FEMP recommended level of lifetime energy cost savings quantity of chiller(s). Best available level of lifetime energy cost savings quantity of chiller(s). Your selection of a ton chiller unit will have a energy cost savings per chiller (over its estimated 23 year life expectancy compared to the base model).

Source: U.S. Department of Energy.

10.13.2 Energy Cost Calculator for Commercial Heat Pumps

(5.4 >=< 20 Tons)

Vary equipment size, energy cost, hours of operation, and /or efficiency level.

INPUT SECTION		
Input the following data (if any parameter is missing, calculator will set to default value).		*Defaults*
Project Type	New Installation	*New Installation*
Condenser Type	Air Source	*Air Source*
Existing Capacity *	ton	—
Existing Cooling Efficiency *	EER	—
Existing Heating Efficiency *	COP	—
Existing IPLV Efficiency *	IPLV	—
New Capacity	ton	*10 tons*
New Cooling Efficiency	EER	*10.1 EER*
New Heating Efficiency	COP	*3.2 COP*
New IPLV Efficiency	IPLV	*10.4 IPLV*
Energy Cost	$ per kWh	*$0.06 per kWh*
Annual Hours of Operation for Cooling	hours	*1500 hours*
Annual Hours of Operation for Heating	hours	*1500 hours*
Quantity of Heat Pumps to be Purchased	unit(s)	*1 unit*

* Existing values should only be entered when Project Type is a replacement.

Calculate Reset

OUTPUT SECTION

Performance per Heat Pump	Your Choice	Existing Heat Pump	Base Model	FEMP Recommended Level	Best Available
Cooling Efficiency	EER				
Heating Efficiency	COP				

Source: U.S. Department of Energy.

10.13.2 Energy Cost Calculator for Commercial Heat Pumps (Continued)

IPLV Efficiency	IPLV				
Annual Energy Use	kWh				
Annual Energy Costs	$	$	$	$	$
Lifetime Energy Costs	$	$	$	$	$
Lifetime Energy Cost Savings	$	$	$	$	$
Lifetime Energy Cost Savings for Heat Pump (s)	$	$	$	$	$

Your selection of a ton heat pump will have a $ energy cost savings per heat pump over an estimated 15 year life expectancy compared to the base model.

Assumptions

- "Base model" has an efficiency that just meets the national minimum standard for that capacity.
- Lifetime energy cost is the sum of the discounted value of the annual energy costs based on assumed commercial heat pump life of 15 years.
- Future electricity price trends and a discount rate of 3.2% are based on Federal guidelines.
- $0.06 for electricity is the Federal average price in the U.S.

Disclaimer

This cost calculator is a screening tool that estimates a product's lifetime energy cost savings at various efficiency levels. Maintenance and installation costs do not vary significantly among the same product having different efficiencies; so, these costs are not included in this calculator tool. For a detailed life-cycle cost analysis, FEMP has developed a tool called Building Life-Cycle Cost (BLCC). This downloadable tool allows the user to vary interest rates, installation costs, maintenance costs, salvage values, and life expectancy for a product or an entire energy project.

Source: U.S. Department of Energy.

10.13.3 Energy Cost Calculator for Commercial Unitary Air Conditioners (Rooftop)

This FEMP energy cost calculator compares the energy costs for your selection with the energy cost for the FEMP recommended rooftop units for various energy costs, efficiency levels, size variations, and hours of operation.

INPUT SECTION

Input the following data (if any parameter is missing, calculator will set it to the default value).		*Defaults*
Condenser Type	Air Source	*Air Source*
Capacity	tons	*10 tons*
Energy Efficiency Ratio	EER	*10.3 EER*
Annual Hours of Operation	hours	*1500 hours*
Energy Cost	$ per kWh	*$0.06 per kWh*
Quantity of Air-Conditioners to be Purchased	unit(s)	*1 unit*

Calculate Reset

OUTPUT SECTION

Performance per Air-Conditioner	Your Choice	Base Model	FEMP Recommended Level	Best Available
Energy Efficiency Ratio	EER			
Annual Energy Use	kWh			
Annual				

Source: U.S. Department of Energy.

10.13.3 Energy Cost Calculator for Commercial Unitary Air Conditioners (Rooftop) (Continued)

Energy Cost	$	$	$	$
Lifetime Energy Cost	$	$	$	$
Lifetime Energy Cost Savings	$	$	$	$
Performance for 1 Air-Conditioner (s)	**Your Choice**	**Base Model**	**FEMP Recommended Level**	**Best Available**
Energy Efficiency Ratio	EER			
Total Annual Energy Use for 1 Air-Conditioner (s)	kWh			
Annual Energy Cost	$	$	$	$
Lifetime Energy Cost	$	$	$	$
Lifetime Energy Cost Savings	$	$	$	$

Your selection of a(n) ton rooftop unit will have a $ energy cost savings per air-conditioner (over its estimated 15 year life expectancy compared to the base model).

Assumptions

- "Base model" has an efficiency that just meets the national minimum standard for that capacity.
- Lifetime Energy Cost is the sum of the discounted value of annual energy costs based on assumed air conditioner life of 15 years. Future electricity price trends and a discount rate of 4.1% are based on Federal guidelines.
- $0.06/kWh is the Federal average electricity price in the U.S.

Disclaimer

This cost calculator is a screening tool that estimates a product's lifetime energy cost savings at various efficiency levels. Maintenance and installation costs do not vary significantly among the same product having different efficiencies; so, these costs are not included in this calculator tool. For a detailed life-cycle cost analysis, FEMP has developed a tool called Building Life-Cycle Cost (BLCC). This downloadable tool allows the user to vary interest rates, installation costs, maintenance costs, salvage values, and life expectancy for a product or an entire energy project.

Source: U.S. Department of Energy.

10.13.3 Energy Cost Calculator for Commercial Unitary Air Conditioners (Rooftop) (Continued)

Capacity tons. Default is 10 tons. Energy Efficiency Ratio EER. Default is 10.3 EER. Annual Hours of Operation. Default is 1500 hours. Energy Cost. Default is $0.06 per kilowatt hour. Quantity of Air-Conditioners to be Purchased in units. Default is 1 unit. Energy Efficiency Ratio your choice EER Energy Efficiency Ratio base model Energy Efficiency Ratio FEMP Recommended Level Energy Efficiency Ratio best available Annual Energy Use kilowatt hour Annual Energy Use base model Annual Energy Use FEMP Recommended Level Annual Energy Use best available Annual Energy Cost dollar amount Annual Energy Cost base model Annual Energy Cost FEMP Recommended Level Annual Energy Cost best available Lifetime Energy Cost dollar amount Lifetime Energy Cost base model Lifetime Energy Cost FEMP Recommended Level Lifetime Energy Cost best available Lifetime Energy Cost Savings dollar amount Lifetime Energy Cost Savings base model Lifetime Energy Cost Savings FEMP Recommended Level Lifetime Energy Cost Savings best available Performance for quantity of air-conditioner(s) Energy Efficiency Ratio your choice EER Energy Efficiency Ratio base model Energy Efficiency Ratio FEMP Recommended Level Energy Efficiency Ratio best available Total Annual Energy Use for quantity of Air-Conditioner(s) Total Annual Energy Use kilowatt hour Total Annual Energy Use base model Total Annual Energy Use FEMP Recommended Level Total Annual Energy Use best available Annual Energy Cost dollar amount Annual Energy Cost base model Annual Energy Cost FEMP Recommended Level Annual Energy Cost best available Lifetime Energy Cost dollar amount Lifetime Energy Cost base model Lifetime Energy Cost FEMP Recommended Level Lifetime Energy Cost best available Lifetime Energy Cost Savings dollar amount Lifetime Energy Cost Savings base model Lifetime Energy Cost Savings FEMP Recommended Level Lifetime Energy Cost Savings best available Your selection of a(n) ton rooftop unit will have a $ energy cost savings per air-conditioner (over its estimated 15 year life expectancy compared to the base model)

Source: U.S. Department of Energy.

10.13.4 Energy Cost Calculator for Commercial Boilers

(Closed Loop, Space Heating Applications Only)

Vary equipment size, energy cost, hours of operation, and /or efficiency level		
INPUT SECTION		
Input the following data (if any parameter is missing, calculator will set to default value).		*Defaults*
Project Type	New Installation	*New Installation*
Deliverable Fluid	Water	*Water*
Fuel Used	Gas	*Gas*
Existing Capacity *	MBtu/h	—
Existing Thermal Efficiency *	% Et	—
New Capacity	MBtu/h**	*5000 MBtu/h*
New Thermal Efficiency	% Et	*80% Et*
Energy Cost	$ per therms	*$0.60 per therm*
Quantity of Boilers to be Purchased	unit(s)	*1 unit*
Annual Hours of Operation***	hours	*1500 hours*

* Existing values should only be entered when Project Type is a replacement.
** 1 MBtu/h = 1000 Btu/h; 1 Therm = 100,000 Btu; 1.4 Therms = 140,000 Btu
*** Value entered should be equivalent full load hours (e.g., 1000 hours @ 50% load equals 500 hours).

Calculate Reset

OUTPUT SECTION

Performance per Boiler	Your Choice	Existing Boiler	Base Model	FEMP Recommended Level	Best Available
Thermal Efficiency	Et				
Annual Energy Use therms					
Annual Energy Costs	$	$	$	$	$
Lifetime Energy Costs	$	$	$	$	$
Lifetime Energy Cost Savings	$	$	$	$	$
Lifetime Energy Cost Savings for Boiler(s)	$	$	$	$	$

Your selection of a MBtu/h boiler will have an energy cost savings of $ over an estimated life of 25 years as compared to the base model.

Source: U.S. Department of Energy.

Section

11

Useful Tables, Charts, and Formulas

Contents

11.0.0 Nails: Penny Designation ("d") and Lengths (U.S. and Metric)

Nail—penny size	Length in inches	Length in millimeters
2d	1	25.40
3d	1 1/4	31.75
4d	1 1/2	38.10
5d	1 3/4	44.45
6d	2	50.80
7d	2 1/4	57.15
8d	2 1/2	63.50
9d	2 3/4	69.85
10d	3	76.20
12d	3 1/4	82.55
16d	3 1/2	88.90
20d	3 3/4	95.25
30d	4 1/2	114.30
40d	5	127.00
50d	5 1/2	139.70
60d	6	152.40

11.1.0 Stainless Steel Sheets (Thickness and Weights)

Gauge	Thickness inches	mm.	Weight lb/ft^2	kg/m^2
8	0.17188	4.3658	7.2187	44.242
10	0.14063	3.5720	5.9062	28.834
11	0.1250	3.1750	5.1500	25.6312
12	0.10938	2.7783	4.5937	22.427
14	0.07813	1.9845	3.2812	16.019
16	0.06250	1.5875	2.6250	12.815
18	0.05000	1.2700	2.1000	10.252
20	0.03750	0.9525	1.5750	7.689
22	0.03125	0.7938	1.3125	6.409
24	0.02500	0.6350	1.0500	5.126
26	0.01875	0.4763	0.7875	3.845
28	0.01563	0.3970	0.6562	3.1816
Plates				
3/16″	0.1875	4.76	7.752	37.85
1/4″	0.25	6.35	10.336	50.46
5/16″	0.3125	7.94	12.920	63.08
3/8″	0.375	9.53	15.503	75.79
1/2″	0.50	12.70	20.671	100.92
5/8″	0.625	15.88	25.839	126.15
3/4″	0.75	19.05	31.007	151.38
1″	1.00	25.4	41.342	201.83

11.2.0 Comparable Thicknesses and Weights of Stainless Steel, Aluminum, and Copper

STAINLESS STEEL			ALUMINUM			COPPER		
Thickness (Inch)	Gauge (U.S. Standard)	Lb/sq ft	Thickness (Inch)	Gauge (B&S)	Lb/sq ft	Thickness (Inch)	Oz sq ft	Lb/sq ft
.010	32	.420	.010	30	.141	.0108	8	.500
.0125	30	.525	.0126	28	.177	.0121	9	.563
						.0135	10	.625
.0156	28	.656	.0156		.220	.0148	11	.688
			.0179	25	.253	.0175	13	.813
.0187	26	.788						
.0219	25	.919	.020	24	.282	.021	16	1.000
.025	24	1.050	.0253	22	.352			
						.027	20	1.250
.031	22	1.313	.0313	—	.441	.032	24	1.500
.0375	20	1.575	.032	20	.451	.0337	28	1.750
			.0403	18	.563	.0431	32	2.000
			.0453	17	.100			
.050	18	2.100	.0506	16	.126			

Note that U.S. Standard Gauge (stainless sheet) is not directly comparable with the B&S Gauge (aluminum). A 20-gauge stainless averages .0375" thick; while a 20-gauge aluminum averages .032" thick; and 20-ounce copper is .027" thick. The higher strength of stainless steel permits use of thinner gauges than required for aluminum or copper, which makes stainless more competitive with aluminum on a weight-to-coverage basis and provides stainless with a substantial weight saving compared to copper. For example, 100 sq ft of .032" aluminum will weigh about 45 pounds, .021" (16-ounce) copper will weigh about 100 pounds, and .015" stainless will weigh about 66 pounds.

11.3.0 Wire and Sheet Metal Gauges and Weights

Name of Gage	*United States Standard Gage		The United States Steel Wire Gage	American or Brown & Sharpe Wire Gage	New Birmingham Standard Sheet & Hoop Gage	British Imperial or English Legal Standard Wire Gage	Birmingham or Stubs Iron Wire Gage	Name of Gage
Principal Use	Uncoated Steel Sheets and Light Plates		Steel Wire except Music Wire	Non-Ferrous Sheets and Wire	Iron and Steel Sheets and Hoops	Wire	Strips, Bands, Hoops and Wire	Principal Use
Gage No.	Weight Oz. per Sq. Ft.	Approx. Thickness Inches	Thickness, Inches					Gage No.
7/0's			.4900		.6666	.500		7/0's
6/0's			.4615	.5800	.625	.464		6/0's
5/0's			.4305	.5165	.5883	.432	.550	5/0's
4/0's			.3938	.4600	.5416	.400	.454	4/0's
3/0's			.3625	.3648	.500	.372	.425	3/0's
2/0's			.3310	.3249	.4452	.348	.380	2/0's
1/0			.3065	.2893	.3964	.324	.340	1/0
1			.2830	.2576	.3532	.300	.300	1
2			.2625	.2294	.3147	.276	.284	2
3	160	.2391	.2437	.2043	.2804	.252	.259	3
4	150	.2242	.2253	.1819	.250	.232	.238	4
5	140	.2092	.2070	.1620	.2225	.212	.220	5
6	130	.1943	.1920	.1443	.1981	.192	.203	6
7	120	.1793	.1770	.1285	.1764	.176	.180	7
8	110	.1644	.1620	.1144	.1570	.160	.165	8
9	100	.1495	.1483	.1019	.1398	.144	.148	9
10	90	.1345	.1350	.0907	.1250	.128	.134	10
11	80	.1196	.1205	.0808	.1113	.116	.120	11
12	70	.1046	.1055	.0720	.0991	.104	.109	12
13	60	.0897	.0915	.0641	.0882	.092	.095	13
14	50	.0747	.0800	.0571	.0785	.080	.083	14
15	45	.0673	.0720	.0508	.0699	.072	.072	15
16	40	.0598	.0625	.0453	.0625	.064	.065	16
17	36	.0538	.0540	.0403	.0556	.056	.058	17
18	32	.0478	.0475	.0359	.0495	.048	.049	18
19	28	.0418	.0410	.0320	.0440	.040	.042	19
20	24	.0359	.0348	.0285	.0392	.036	.035	20
21	22	.0329	.0317	.0253	.0349	.032	.032	21
22	20	.0299	.0286	.0226	.0313	.028	.028	22
23	18	.0269	.0258	.0201	.0278	.024	.025	23
24	16	.0239	.0230	.0179	.0248	.022	.022	24
25	14	.0209	.0204	.0159	.0220	.020	.020	25
26	12	.0179	.0181	.0142	.0196	.018	.018	26
27	11	.0164	.0173	.0126	.0175	.0164	.016	27
28	10	.0149	.0162	.0113	.0156	.0148	.014	28
29	9	.0135	.0150	.0100	.0139	.0136	.013	29
30	8	.0120	.0140	.0089	.0123	.0124	.012	30
31	7	.0105	.0132	.0080	.0110	.0116	.010	31
32	6.5	.0097	.0128	.0071	.0098	.0108	.009	32
33	6	.0090	.0118	.0063	.0087	.0100	.008	33
34	5.5	.0082	.0104	.0056	.0077	.0092	.007	34
35	5	.0075	.0095	.0050	.0069	.0084	.005	35
36	4.5	.0067	.0090	.0045	.0061	.0076	.004	36
37	4.25	.0064	.0085	.0040	.0054	.0068		37
38	4	.0060	.0080	.0035	.0048	.0060		38
39			.0075	.0031	.0043	.0052		39
40			.0070		.0039	.0048		40

* U.S. Standard Gage is officially a weight gage, in oz per sq ft as tabulated. The Approx. Thickness shown is the "Manufacturers' Standard" of the American Iron and Steel Institute, based on steel as weighing 501.81 lb per cu ft (489.6 true weight plus 2.5 percent for average over-run in area and thickness).

11.4.0 Weights and Specific Gravities of Common Materials

Substance	Weight Lb per Cu Ft	Specific Gravity
METALS, ALLOYS, ORES		
Aluminum, cast, hammered	165	2.55-2.75
Brass, cast, rolled	534	8.4-8.7
Bronze, 7.9 to 14% Sn	509	7.4-8.9
Bronze, aluminum	481	7.7
Copper, cast, rolled	556	8.8-9.0
Copper ore, pyrites	262	4.1-4.3
Gold, cast, hammered	1205	19.25-19.3
Iron, cast, pig	450	7.2
Iron, wrought	485	7.6-7.9
Iron, spiegel-eisen	468	7.5
Iron, ferro-silicon	437	6.7-7.3
Iron ore, hematite	325	5.2
Iron ore, hematite in bank	160-180	....
Iron ore, hematite loose	130-160	....
Iron ore, limonite	237	3.6-4.0
Iron ore, magnetite	315	4.9-5.2
Iron slag	172	2.5-3.0
Lead	710	11.37
Lead ore, galena	465	7.3-7.6
Magnesium, alloys	112	1.74-1.83
Manganese	475	7.2-8.0
Manganese ore, pyrolusite	259	3.7-4.6
Mercury	849	13.6
Monel Metal	556	8.8-9.0
Nickel	565	8.9-9.2
Platinum, cast, hammered	1330	21.1-21.5
Silver, cast, hammered	656	10.4-10.5
Steel, rolled	490	7.85
Tin, cast, hammered	459	7.2-7.5
Tin ore, cassiterite	418	6.4-7.0
Zinc, cast, rolled	440	6.9-7.2
Zinc ore, blende	253	3.9-4.2
VARIOUS SOLIDS		
Cereals, oats, bulk	32	....
Cereals, barley, bulk	39	....
Cereals, corn, rye, bulk	48	....
Cereals, wheat, bulk	48	....
Hay and Straw, bales	20	....
Cotton, Flax, Hemp	93	1.47-1.50
Fats	58	0.90-0.97
Flour, loose	28	0.40-0.50
Flour, pressed	47	0.70-0.80
Glass, common	156	2.40-2.60
Glass, plate or crown	161	2.45-2.72
Glass, crystal	184	2.90-3.00
Leather	59	0.86-1.02
Paper	58	0.70-1.15
Potatoes, piled	42	....
Rubber, caoutchouc	59	0.92-0.96
Rubber goods	94	1.0-2.0
Salt, granulated, piled	48	....
Saltpeter	67	....
Starch	96	1.53
Sulphur	125	1.93-2.07
Wool	82	1.32
TIMBER, U. S. SEASONED		
Moisture Content by Weight:		
Seasoned timber 15 to 20%		
Green timber up to 50%		
Ash, white, red	40	0.62-0.65
Cedar, white, red	22	0.32-0.38
Chestnut	41	0.66
Cypress	30	0.48
Fir, Douglas spruce	32	0.51
Fir, eastern	25	0.40
Elm, white	45	0.72
Hemlock	29	0.42-0.52
Hickory	49	0.74-0.84
Locust	46	0.73
Maple, hard	43	0.68
Maple, white	33	0.53
Oak, chestnut	54	0.86
Oak, live	59	0.95
Oak, red, black	41	0.65
Oak, white	46	0.74
Pine, Oregon	32	0.51
Pine, red	30	0.48
Pine, white	26	0.41
Pine, yellow, long-leaf	44	0.70
Pine, yellow, short-leaf	38	0.61
Poplar	30	0.48
Redwood, California	26	0.42
Spruce, white, black	27	0.40-0.46
Walnut, black	38	0.61
Walnut, white	26	0.41
VARIOUS LIQUIDS		
Alcohol, 100%	49	0.79
Acids, muriatic 40%	75	1.20
Acids, nitric 91%	94	1.50
Acids, sulphuric 87%	112	1.80
Lye, soda 66%	106	1.70
Oils, vegetable	58	0.91-0.94
Oils, mineral, lubricants	57	0.90-0.93
Water, 4°C. max. density	62.428	1.0
Water, 100°C.	59.830	0.9584
Water, ice	56	0.88-0.92
Water, snow, fresh fallen	8	.125
Water, sea water	64	1.02-1.03
GASES		
Air, 0°C. 760 mm.	.08071	1.0
Ammonia	.0478	0.5920
Carbon dioxide	.1234	1.5291
Carbon monoxide	.0781	0.9673
Gas, illuminating	.028-.036	0.35-0.45
Gas, natural	.038-.039	0.47-0.48
Hydrogen	.00559	0.0693
Nitrogen	.0784	0.9714
Oxygen	.0892	1.1056

The specific gravities of solids and liquids refer to water at 4°C, those of gases to air at 0°C and 760 mm. pressure. The weights per cubic foot are derived from average specific gravities, except where stated that weights are for bulk, heaped or loose material, etc.

11.4.0 Weights and Specific Gravities of Common Materials (Continued)

Substance	Weight Lb per Cu Ft	Specific Gravity
ASHLAR MASONRY		
Granite, syenite, gneiss	165	2.3-3.0
Limestone, marble	160	2.3-2.8
Sandstone, bluestone	140	2.1-2.4
MORTAR RUBBLE MASONRY		
Granite, syenite, gneiss	155	2.2-2.8
Limestone, marble	150	2.2-2.6
Sandstone, bluestone	130	2.0-2.2
DRY RUBBLE MASONRY		
Granite, syenite, gneiss	130	1.9-2.3
Limestone, marble	125	1.9-2.1
Sandstone, bluestone	110	1.8-1.9
BRICK MASONRY		
Pressed brick	140	2.2-2.3
Common brick	120	1.8-2.0
Soft brick	100	1.5-1.7
CONCRETE MASONRY		
Cement, stone, sand	144	2.2-2.4
Cement, slag, etc.	130	1.9-2.3
Cement, cinder, etc.	100	1.5-1.7
VARIOUS BUILDING MATERIALS		
Ashes, cinders	40-45	......
Cement, portland, loose	90	......
Cement, portland, set	183	2.7-3.2
Lime, gypsum, loose	53-64	......
Mortar, set	103	1.4-1.9
Slags, bank slag	67-72	......
Slags, bank screenings	98-117	......
Slags, machine slag	96	......
Slags, slag sand	49-55	......
EARTH, ETC., EXCAVATED		
Clay, dry	63	......
Clay, damp, plastic	110	......
Clay and gravel, dry	100	......
Earth, dry, loose	76	......
Earth, dry, packed	95	......
Earth, moist, loose	78	......
Earth, moist, packed	96	......
Earth, mud, flowing	108	......
Earth, mud, packed	115	......
Riprap, limestone	80-85	......
Riprap, sandstone	90	......
Riprap, shale	105	......
Sand, gravel, dry, loose	90-105	......
Sand, gravel, dry, packed	100-120	......
Sand, gravel, wet	118-120	......
EXCAVATIONS IN WATER		
Sand or gravel	60	......
Sand or gravel and clay	65	......
Clay	80	......
River mud	90	......
Soil	70	......
Stone riprap	65	......

Substance	Weight Lb per Cu Ft	Specific Gravity
MINERALS		
Asbestos	153	2.1-2.8
Barytes	281	4.50
Basalt	184	2.7-3.2
Bauxite	159	2.55
Borax	109	1.7-1.8
Chalk	137	1.8-2.6
Clay, marl	137	1.8-2.6
Dolomite	181	2.9
Feldspar, orthoclase	159	2.5-2.6
Gneiss, serpentine	159	2.4-2.7
Granite, syenite	175	2.5-3.1
Greenstone, trap	187	2.8-3.2
Gypsum, alabaster	159	2.3-2.8
Hornblende	187	3.0
Limestone, marble	165	2.5-2.8
Magnesite	187	3.0
Phosphate rock, apatite	200	3.2
Porphyry	172	2.6-2.9
Pumice, natural	40	0.37-0.90
Quartz, flint	165	2.5-2.8
Sandstone, bluestone	147	2.2-2.5
Shale, slate	175	2.7-2.9
Soapstone, talc	169	2.6-2.8
STONE, QUARRIED, PILED		
Basalt, granite, gneiss	96	—
Limestone, marble, quartz	95	—
Sandstone	82	—
Shale	92	—
Greenstone, hornblende	107	—
BITUMINOUS SUBSTANCES		
Asphaltum	81	1.1-1.5
Coal, anthracite	97	1.4-1.7
Coal, bituminous	84	1.2-1.5
Coal, lignite	78	1.1-1.4
Coal, peat, turf, dry	47	0.65-0.85
Coal, charcoal, pine	23	0.28-0.44
Coal, charcoal, oak	33	0.47-0.57
Coal, coke	75	1.0-1.4
Graphite	131	1.9-2.3
Paraffine	56	0.87-0.91
Petroleum	54	0.87
Petroleum, refined	50	0.79-0.82
Petroleum, benzine	46	0.73-0.75
Petroleum, gasoline	42	0.66-0.69
Pitch	69	1.07-1.15
Tar, bituminous	75	1.20
COAL AND COKE, PILED		
Coal, anthracite	47-58	—
Coal, bituminous, lignite	40-54	—
Coal, peat, turf	20-26	—
Coal, charcoal	10-14	—
Coal, coke	23-32	—

The specific gravities of solids and liquids refer to water at 4°C, those of gases to air at 0°C and 760 mm. pressure. The weights per cubic foot are derived from average specific gravities, except where stated that weights are for bulk, heaped or loose material, etc.

11.5.0 Useful Formulas

Circumference of a circle = π × *diameter* or 3.1416 × *diameter*

Diameter of a circle = *circumference* × 0.31831

Area of a square = *length* × *width*

Area of a rectangle = *length* × *width*

Area of a parallelogram = *base* × *perpendicular height*

Area of a triangle = ½ *base* × *perpendicular height*

Area of a circle = π *radius squared or diameter squared* × 0.7854

Area of an ellipse = *length* × *width* × 0.7854

Volume of a cube or rectangular prism = *length* × *width* × *height*

Volume of a triangular prism = *area of triangle* × *length*

Volume of a sphere = *diameter cubed* × 0.5236 (*diameter* × *diameter* × *diameter* × 0.5236)

Volume of a cone = π × *radius squared* × ⅓ *height*

Volume of a cylinder = π × *radius squared* × *height*

Length of one side of a square × 1.128 = *diameter of an equal circle*

Doubling the diameter of a pipe or cylinder increases its capacity 4 times

Pressure (in lb/sq in.) *of a column of water* = *height of the column* (in feet) × 0.434

Capacity of a pipe or tank (in U.S. gallons) = *diameter squared* (in inches) × *length* (in inches) × 0.0034

1 gal water = 8⅓ lb = 231 cu in.

1 cu ft water = 62½ lb = 7½ gal.

11.6.0 Decimal Equivalents of Inches in Feet and Yards

Inches	Feet	Yards
1	.0833	.0278
2	.1667	.0556
3	.2500	.0833
4	.333	.1111
5	.4166	.1389
6	.5000	.1667
7	.5833	.1944
8	.6667	.2222
9	.7500	.2500
10	.8333	.2778
11	.9166	.3056
12	1.000	.3333

11.7.0 Conversion of Fractions to Decimals

Fractions	Decimal	Fractions	Decimal
1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	38/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.1719	43/64	.67187
3/16	.1875	11/16	.6875
13/64	.2031	45/64	.70312
7/32	.2188	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/10	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.398625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	60/64	.921875
7/16	.4375	15/16	.9375
20/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.50	1"	1.000000

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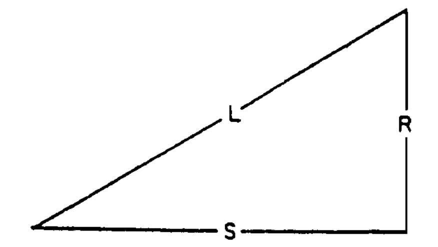
11.7.1 Fraction/Decimal/Millimeter Conversion Table

FRACTION	DECIMAL	MILLIMETER
1/64	0.01563	0.3969
1/32	0.03125	0.7938
3/64	0.04688	1.1906
1/16	0.06250	1.5875
5/64	0.07813	1.9844
3/32	0.09375	2.3813
7/64	0.10937	2.7781
1/8	**0.12500**	**3.1750**
9/64	0.14063	3.5719
5/32	0.15625	3.9688
11/64	0.17188	4.3656
3/16	0.18750	4.7625
13/64	0.20312	5.1594
7/32	0.21875	5.5563
15/64	0.23438	5.9531
1/4	**0.25000**	**6.3500**
17/64	0.26563	6.7469
9/32	0.28125	7.1438
19/64	0.29688	7.5406
5/16	0.31250	7.9375
21/64	0.32813	8.3344
11/32	0.34375	8.7313
23/64	0.35938	9.1281
3/8	**0.37500**	**9.5250**
25/64	0.39063	9.9219
13/32	0.40625	10.3188
27/64	0.42188	10.7156
7/16	0.43750	11.1125
29/64	0.45313	11.5094
15/32	0.46875	11.9063
31/64	0.48438	12.3031
1/2	**0.50000**	**12.7000**
33/64	0.51563	13.0969
17/32	0.53125	13.4938
35/64	0.54688	13.8906
9/16	0.56250	14.2875
37/64	0.57813	14.6844
19/32	0.59375	15.0813
39/64	0.60938	15.4781
5/8	**0.62500**	**15.8750**
41/64	0.64063	16.2719
21/32	0.65625	16.6688
43/64	0.67188	17.0656
11/16	0.68750	17.4625
45/64	0.70313	17.8594
23/32	0.71875	18.2563
47/64	0.73438	18.6531
3/4	**0.75000**	**19.0500**
49/64	0.76563	19.4469
25/32	0.78125	19.8438
51/64	0.79688	20.2406
13/16	0.81250	20.6375
53/64	0.82813	21.0344
27/32	0.84375	21.4313
55/64	0.85938	21.8281
7/8	**0.87500**	**22.2250**
57/64	0.89063	22.6219
29/32	0.90625	23.0188
59/64	0.92188	23.4156
15/16	0.93750	23.8125
61/64	0.95313	24.2094
31/32	0.96875	24.6063
63/64	0.98438	25.0031
1	**1.00000**	**25.4000**

11.7.2 Decimals of an Inch for Each 1/64 in., with Millimeter Equivalents

Fraction	1/64ths	Decimal	Millimeters (Approx.)	Fraction	1/64ths	Decimal	Millimeters (Approx.)
...	1	.015625	0.397	...	33	.515625	13.097
1/32	2	.03125	0.794	17/32	34	.53125	13.494
...	3	.046875	1.191	...	35	.546875	13.891
1/16	4	.0625	1.588	9/16	36	.5625	14.288
...	5	.078125	1.984	...	37	.578125	14.684
3/32	6	.09375	2.381	19/32	38	.59375	15.081
...	7	.109375	2.778	...	39	.609375	15.478
1/8	8	.125	3.175	5/8	40	.625	15.875
...	9	.140625	3.572	...	41	.640625	16.272
5/32	10	.15625	3.969	21/32	42	.65625	16.669
...	11	.171875	4.366	...	43	.671875	17.066
3/16	12	.1875	4.763	11/16	44	.6875	17.463
...	13	.203125	5.159	...	45	.703125	17.859
7/32	14	.21875	5.556	23/32	46	.71875	18.256
...	15	.234375	5.953	...	47	.734375	18.653
1/4	16	.250	6.350	3/4	48	.750	19.050
...	17	.265625	6.747	...	49	.765625	19.447
9/32	18	.28125	7.144	25/32	50	.78125	19.844
...	19	.296875	7.541	...	51	.796875	20.241
5/16	20	.3125	7.938	13/16	52	.8125	20.638
...	21	.328125	8.334	...	53	.828125	21.034
11/32	22	.34375	8.731	27/32	54	.84375	21.431
...	23	.359375	9.128	...	55	.859375	21.828
3/8	24	.375	9.525	7/8	56	.875	22.225
...	25	.390625	9.922	...	57	.890625	22.622
13/32	26	.40625	10.319	29/32	58	.90625	23.019
...	27	.421875	10.716	...	59	.921875	23.416
7/16	28	.4375	11.113	15/16	60	.9375	23.813
...	29	.453125	11.509	...	61	.953125	24.209
15/32	30	.46875	11.906	31/32	62	.96875	24.606
...	31	.484375	12.303	...	63	.984375	25.003
1/2	32	.500	12.700	1	64	1.000	25.400

11.8.0 Solutions of the Right Triangle



To find side	When you know side	Multiply side	For 45 Ells-By	For 22 1/2 Ells-By	For 67 1/2 Ells-By	For 72 Ells-By	For 60 Ells-By	For 80 Ells-By
L	S	S	1.4142	2.6131	1.08	1.05	1.1547	2.00
S	L	L	.707	.3826	.92	.95	.866	.50
R	S	S	1.000	2.4142	.414	.324	.5773	.1732
S	R	R	1.000	.4142	2.41	3.07	1.732	.5773
L	R	R	1.4142	1.0824	2.61	3.24	2.00	1.1547
R	L	L	.7071	.9239	.38	.31	.50	.866

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11.9.0 Areas and Other Formulas

Parallelogram	*Area* = *base* × *distance between the two parallel sides*
Pyramid	*Area* = ½ *perimeter of base* × *slant height* + *area of base* *Volume* = *area of base* × ⅓ *of the altitude*
Rectangle	*Area* = *length* × *width*
Rectangular prisms	*Volume* = *width* × *height* × *length*
Sphere	*Area of surface* = *diameter* × *diameter* × 3.1416 *Side of inscribed cube* = *radius* × 1.547 *Volume* = *diameter* × *diameter* × *diameter* × 0.5236
Square	*Area* = *length* × *width*
Triangle	*Area* = *one half of height times base*
Trapezoid	*Area* = *one half of the sum of the parallel sides* × *height*
Cone	*Area of surface* = *one half of circumference of base* × *slant height* + *area of base* *Volume* = *diameter* × *diameter* × 0.7854 × *one third of the altitude*
Cube	*Volume* = *width* × *height* × *length*
Ellipse	*Area* = *short diameter* × *long diameter* × 0.7854
Cylinder	*Area of surface* = *diameter* × 3.1416 × *length* + *area of the two bases* *Area of base* = *diameter* × *diameter* × 0.7854 *Area of base* = *volume* + *length* *Length* = *volume* + *area of base* *Volume* = *length* × *area of base* *Capacity in gallons* = *volume in inches* + 231 *Capacity of gallons* = *diameter* × *diameter* × *length* × 0.0034 *Capacity in gallons* = *volume in feet* × 7.48
Circle	*Circumference* = *diameter* × 3.1416 *Circumference* = *radius* × 6.2832 *Diameter* = *radius* × 2 *Diameter* = *square root of* = (*area* + 0.7854) *Diameter* = *square root of area* × 1.1283

11.10.0 Volume of Vertical Cylindrical Tanks (in Gallons per Foot of Depth)

Diameter in Feet	Diameter in Inches	U. S. Gallons	Diameter in Feet	Diameter in Inches	U. S. Gallons	Diameter in Feet	Diameter in Inches	U. S. Gallons
1	0	5.875	3	6	71.97	6	0	211.5
1	1	6.895	3	7	75.44	6	3	220.5
1	2	7.997	3	8	78.99	6	6	248.2
1	3	9.180	3	9	82.62	6	9	267.7
1	4	10.44	3	10	86.33	7	0	287.9
1	5	11.79	3	11	90.13	7	3	308.8
1	6	13.22	4	0	94.00	7	6	330.5
1	7	14.73	4	1	97.96	7	9	352.9
1	8	16.32	4	2	102.0	8	0	376.0
1	9	17.99	4	3	106.1	8	3	399.9
1	10	19.75	4	4	110.3	8	6	424.5
1	11	21.58	4	5	114.6	8	9	449.8
2	0	23.50	4	6	119.0	9	0	475.9
2	1	25.50	4	7	123.4	9	3	502.7
2	2	27.58	4	8	127.9	9	6	530.2
2	3	29.74	4	9	132.6	9	9	558.5
2	4	31.99	4	10	137.3	10	0	587.5
2	5	34.31	4	11	142.0	10	3	617.3
2	6	36.72	5	0	146.9	10	6	647.7
2	7	39.21	5	1	151.8	10	9	679.0
2	8	41.78	5	2	156.8	11	0	710.9
2	9	44.43	5	3	161.9	11	3	743.6
2	10	47.16	5	4	167.1	11	6	777.0
2	11	49.98	5	5	172.4	11	9	811.1
3	0	52.88	5	6	177.7	12	0	846.0
3	1	55.86	5	7	183.2	12	3	881.6
3	2	58.92	5	8	188.7	12	6	918.0
3	3	62.06	5	9	194.2	12	9	955.1
3	4	65.28	5	10	199.9			
3	5	68.58	5	11	205.7			

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11.11.0 Volume of Rectangular Tank Capacities (in U.S. Gallons per Foot of Depth)

Width Feet	LENGTH OF TANK — IN FEET						
	2	2 1/2	3	3 1/2	4	4 1/2	5
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81
2 1/2	—	46.75	56.10	65.45	74.81	84.16	93.51
3	—	—	67.32	78.55	89.77	101.0	112.2
3 1/2	—	—	—	91.64	104.7	117.8	130.9
4	—	—	—	—	119.7	134.6	149.6
4 1/2	—	—	—	—	—	151.5	168.3
5	—	—	—	—	—	—	187.0
	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2
2	82.29	89.77	97.25	104.7	112.2	119.7	127.2
2 1/2	102.9	112.2	121.6	130.9	140.3	149.6	159.0
3	123.4	134.6	145.9	157.1	168.3	179.5	190.8
3 1/2	144.0	157.1	170.2	183.3	196.4	209.5	222.5
4	164.6	179.5	194.5	209.5	224.4	239.4	254.3
4 1/2	185.1	202.0	218.8	235.6	252.5	269.3	286.1
5	205.7	224.4	243.1	261.8	280.5	299.2	317.9
5 1/2	226.3	246.9	267.4	288.0	308.6	329.1	349.7
6	—	269.3	291.7	314.2	336.6	359.1	381.5
6 1/2	—	—	316.1	340.4	364.7	389.0	413.3
7	—	—	—	366.5	392.7	418.9	445.1
7 1/2	—	—	—	—	420.8	448.8	476.9
8	—	—	—	—	—	478.8	508.7
8 1/2	—	—	—	—	—	—	540.5
	9	9 1/2	10	10 1/2	11	11 1/2	12
2	134.6	142.1	149.6	157.1	164.6	172.1	179.5
2 1/2	168.3	177.7	187.0	196.4	205.7	215.1	224.4
3	202.0	213.2	224.4	235.6	246.9	258.1	269.3
3 1/2	235.6	248.7	261.8	274.9	288.0	301.1	314.2
4	269.3	284.3	299.2	314.2	329.1	344.1	359.1
4 1/2	303.0	319.8	336.6	353.5	370.3	387.1	403.9
5	336.6	355.3	374.0	392.7	411.4	430.1	448.8
5 1/2	370.3	390.9	411.4	432.0	452.6	473.1	493.7
6	403.9	426.4	448.8	471.3	493.7	516.2	538.6
6 1/2	437.6	461.9	486.2	510.5	534.9	559.2	583.5
7	471.3	497.5	523.6	549.8	576.0	602.2	628.4
7 1/2	504.9	533.0	561.0	589.1	617.1	645.2	673.2
8	538.6	568.5	598.4	628.4	658.3	688.2	718.1
8 1/2	572.3	604.1	635.8	667.6	699.4	731.2	763.0
9	605.9	639.6	673.2	706.9	740.6	774.2	807.9
9 1/2	—	675.1	710.6	746.2	781.7	817.2	852.8
10	—	—	748.1	785.5	822.9	860.3	897.7
10 1/2	—	—	—	824.7	864.0	903.3	942.5
11	—	—	—	—	905.1	946.3	987.4
11 1/2	—	—	—	—	—	989.3	1032.0
12	—	—	—	—	—	—	1077.0

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11.12.0 Capacity of Horizontal Cylindrical Tanks

% Depth Filled	% of Capacity	% Depth Filled	% of Capacity	% Depth Filled	% of Capacity	% Depth Filled	% of Capacity
1	.20	26	20.73	51	51.27	76	81.50
2	.50	27	21.86	52	52.55	77	82.60
3	.90	28	23.00	53	53.81	78	83.68
4	1.34	29	24.07	54	55.08	79	84.74
5	1.87	30	25.31	55	56.34	80	85.77
6	2.45	31	26.48	56	57.60	81	86.77
7	3.07	32	27.66	57	58.86	82	87.76
8	3.74	33	28.84	58	60.11	83	88.73
9	4.45	34	30.03	59	61.36	84	89.68
10	5.20	35	31.19	60	62.61	85	90.60
11	5.98	36	32.44	61	63.86	86	91.50
12	6.80	37	33.66	62	65.10	87	92.36
13	7.64	38	34.90	63	66.34	88	93.20
14	8.50	39	36.14	64	67.56	89	94.02
15	9.40	40	37.36	65	68.81	90	94.80
16	10.32	41	38.64	66	69.97	91	95.50
17	11.27	42	39.89	67	71.16	92	96.26
18	12.24	43	41.14	68	72.34	93	96.93
19	13.23	44	42.40	69	73.52	94	97.55
20	14.23	45	43.66	70	74.69	95	98.13
21	15.26	46	44.92	71	75.93	96	98.66
22	16.32	47	46.19	72	77.00	97	99.10
23	17.40	48	47.45	73	78.14	98	99.50
24	18.50	49	48.73	74	79.27	99	99.80
25	19.61	50	50.00	75	80.39	100	100.00

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11.13.0 Round-Tapered Tank Capacities

$$Volume = \frac{h^3}{3} \frac{[(Area_{\text{Top}} + Area_{\text{Base}}) + \sqrt{(Area_{\text{Top}} + Area_{\text{Base}})}]}{231}$$

If inches are used.

$$Volume = \frac{h}{3} [(Area_{\text{Base}} + Area_{\text{Top}}) + \sqrt{(Area_{\text{Base}} + Area_{\text{Top}})}] \times 7.48$$

If feet are used.

Sample Problem

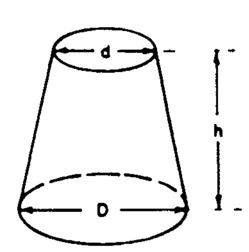
Let d be 12" (2 ft)
D be 36" (3 ft)
h be 48" (4 ft)
Find volume in gallons.

$$Volume = \frac{48}{3} \frac{[(\pi \times 12^2) + (\pi + 18^2) + \sqrt{\pi\ 12^2 \times 18^2}]}{231}$$

Where dimensions are in inches

$$Volume = \frac{4}{3} [(\pi \times 12^2) + (\pi + 1\tfrac{1}{2}^2) + \sqrt{(\pi \times 1^2) \times \tfrac{1}{2}^2}] \times 7.48$$

Where dimensions are in feet



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11.14.0 Circumferences and Areas of Circles

Of One Inch					Of Inches or Feet				
Fract.	Decimal	Circ.	Area	Dia.	Circ.	Area	Dia.	Circ.	Area
1/64	.015625	.04909	.00019	1	3.1416	.7854	64	201.06	3216.99
1/32	.03125	.09818	.00077	2	6.2832	3.1416	65	204.20	3318.31
3/64	.046875	.14726	.00173	3	9.4248	7.0686	66	207.34	3421.19
1/16	.0625	.19635	.00307	4	12.5664	12.5664	67	210.49	3525.65
5/64	.078125	.24545	.00479	5	15.7080	19.635	68	213.63	3631.68
3/32	.09375	.29452	.00690	6	18.850	28.274	69	216.77	3739.28
7/64	.109375	.34363	.00939	7	21.991	38.485	70	219.91	3848.45
1/8	.125	.39270	.01227	8	25.133	50.266	71	223.05	3959.19
9/64	.140625	.44181	.01553	9	28.274	63.617	72	226.19	4071.50
5/32	.15625	.49087	.01917	10	31.416	78.540	73	229.34	4185.50
11/64	.171875	.53999	.02320	11	34.558	95.033	74	232.48	4300.84
3/16	.1875	.58.905	.02761	12	37.699	113.1	75	235.62	4417.86
13/64	.203125	.63817	.03241	13	40.841	132.73	76	238.76	4536.46
7/32	.21875	.68722	.03757	4	43.982	153.94	77	241.90	4656.63
15/64	.234375	.73635	.04314	15	47.124	176.71	78	245.04	4778.36
1/4	.25	.78540	.04909	16	50.265	201.06	79	248.19	4901.67
17/64	.265625	.83453	.05542	17	53.407	226.98	80	251.33	5026.55
9/32	.28125	.88357	.06213	18	56.549	254.47	81	254.47	5153.0
10/64	.296875	.93271	.06922	19	59.690	283.53	82	257.61	5281.02
5/16	.3125	.98175	.07670	20	63.832	314.16	83	260.75	5410.61
21/64	.328125	1.0309	.08456	21	65.973	346.36	84	263.89	5541.77
11/32	.34375	1.0799	.09281	22	69.115	380.13	85	267.04	5674.50
23/64	.35975	1.1291	.10144	23	72.257	415.48	86	270.18	5808.80
3/8	.375	1.1781	.11045	24	75.398	452.39	87	273.32	5944.68
25/64	.390625	1.2273	.11984	25	78.540	490.87	88	276.46	6082.12
13/32	.40625	1.2763	.12962	26	81.681	530.93	89	279.60	6221.14
27/64	.421875	1.3254	.13979	27	84.823	572.56	90	282.74	6361.71
7/16	.4375	1.3744	.15033	28	87.965	615.75	91	258.88	6503.88
29/64	.453125	1.4236	.16126	29	91.106	660.52	92	289.03	6647.61
15/32	.46875	1.4726	.17257	30	94.248	706.86	93	292.17	6792.91
31/64	.484375	1.5218	.18427	31	97.389	754.77	94	295.31	6939.78
1/2	.5	1.5708	.19635	32	100.53	804.25	95	298.45	7088.22

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11.14.0 Circumferences and Areas of Circles (Continued)

Of One Inch					Of Inches or Feet				
Fract.	Decimal	Circ.	Area	Dia.	Circ.	Area	Dia.	Circ.	Area
33/64	.515625	1.6199	.20880	33	103.67	855.30	96	301.59	7238.23
17/32	.53125	1.6690	.22166	34	106.81	907.92	97	304.73	7339.81
35/64	.546875	1.7181	.23489	35	109.96	962.11	98	307.88	7542.96
9/16	.5625	1.7671	.24850	36	113.10	1017.88	99	311.02	7697.69
37/64	.578125	1.8163	.26248	37	116.24	1075.21	100	314.16	7853.98
19/32	.59375	1.8653	.27688	38	119.38	1134.11	101	317.30	8011.85
30/64	.609375	1.9145	.29164	39	122.52	1194.59	102	320.44	8171.28
5/8	.625	1.9635	.30680	40	125.66	1256.64	103	323.58	8332.29
41/64	.640625	2.0127	.32232	41	128.81	1320.25	104	326.73	8494.87
21/32	.65625	2.0617	33824	42	131.95	1385.44	105	327.87	8659.01
43/64	.671875	2.1108	.35453	43	135.09	1452.20	106	333.01	8824.73
11/16	.6875	2.1598	.37122	44	138.23	1520.53	107	336.15	1992.02
45/64	.703125	2.2090	.38828	45	141.37	1590.43	108	339.29	9160.88
23/32	.71875	2.2580	.40574	46	144.51	1661.90	109	342.43	9331.32
47/64	.734375	2.3072	.42356	47	147.65	1734.94	110	345.58	9503.32
3/4	.75	2.3562	.44179	48	150.80	1809.56	111	348.72	9676.89
49/64	.765625	2.4050	.45253	49	153.94	1885.74	112	351.86	9853.03
23/32	.78125	2.4544	.47937	50	157.08	1963.50	113	355.0	10028.75
51/64	.796875	2.5036	.49872	51	160.22	2042.82	114	358.14	10207.03
13/16	.8125	2.5525	.51849	52	163.36	2123.72	115	361.28	10386.89
53/64	.828125	2.6017	.53862	53	166.50	2206.18	116	364.42	10568.32
27/32	.84375	2.6507	.55914	54	169.65	2290.22	117	367.57	10751.32
55/64	.859375	2.6999	.58003	55	172.79	2375.83	118	370.71	10935.88
7/8	.875	2.7489	.60123	56	175.93	2463.01	119	373.85	11122.02
57/64	.890625	2.7981	.62298	57	179.07	2551.76	120	376.99	11309 '3
29/32	.90625	2.8471	.64504	58	182.21	2642.08	121	380.13	11499 01
59/64	.921875	2.8963	.66746	59	185.35	2733.97	122	383.27	11689.07
15/16	.9375	2.9452	.69029	60	188.50	2827.43	123	386.42	11882.29
61/64	.953125	2.9945	.71349	61	191.64	2922.47	124	389.56	12076.28
31/32	.96875	3.0434	.73708	62	194.78	3019.07	125	392.70	12271.85
63/64	.984375	3.0928	.76097	63	197.92	3117.25	126	395.84	12468.98

By permission of Cast Iron Soil Pipe Institute.

11.15.0 Tap and Drill Sizes for Fractional Size Threads

Approximately 65% Depth Thread / AMERICAN NATIONAL THREAD FORM

Tap Size	Threads per Inch	Hole Diameter	Drill
1/16	72	.049	3/64
1/16	64	.047	3/64
1/16	60	.046	56
5/64	72	.065	52
5/64	64	.063	1/16
5/64	60	.062	1/16
5/64	56	.061	53
3/32	60	.077	5/64
3/32	56	.076	48
3/32	50	.074	49
3/32	48	.073	49
7/64	56	.092	42
7/64	50	.090	43
7/64	48	.089	43
1/8	48	.105	36
1/8	40	.101	38
1/8	36	.098	40
1/8	32	.095	3/32
9/64	40	.116	32
9/64	36	.114	33
9/64	32	.110	35
5/32	40	.132	30
5/32	36	.129	30
5/32	32	.126	1/8
11/64	36	.145	27
11/64	32	.141	9/64
3/16	36	.161	20
3/16	32	.157	22
3/16	30	.155	23
3/16	24	.147	26
13/64	32	.173	17
13/64	30	.171	11/64
13/64	24	.163	20
7/32	32	.188	12
7/32	28	.184	13
7/32	24	.178	16
15/64	32	.204	6
15/64	28	.200	8
15/64	24	.194	10
1/4	32	.220	7/32
1/4	28	.215	3
1/4	27	.214	3
1/4	24	.209	4
1/4	20	.201	7
5/16	32	.282	9/32
5/16	27	.276	J
5/16	24	.272	I
5/16	20	.264	17/64
5/16	18	.258	F
3/8	27	.339	R
3/8	24	.334	Q
3/8	20	.326	21/64
3/8	16	.314	5/16
7/16	27	.401	Y
7/16	24	.397	X
7/16	20	.389	25/64
7/16	14	.368	U
1/2	27	.464	15/32
1/2	24	.460	29/64
1/2	20	.451	29/64
1/2	13	.425	27/64
1/2	12	.419	27/64
9/16	27	.526	17/32
9/16	18	.508	33/64
9/16	12	.481	31/64
5/8	27	.589	19/32
5/8	18	.571	37/64
5/8	12	.544	35/64
5/8	11	.536	17/32
11/16	16	.627	5/8
11/16	11	.599	19/32
3/4	27	.714	23/32
3/4	16	.689	11/16
3/4	12	.669	43/64
3/4	10	.653	21/32
13/16	12	.731	47/64
13/16	10	.715	23/32
7/8	27	.839	27/32
7/8	18	.821	53/64
7/8	14	.805	13/16
7/8	12	.794	51/64
7/8	9	.767	49/64
15/16	12	.856	55/64
15/16	9	.829	53/64
1	27	.964	31/32
1	14	.930	15/16
1	12	.919	59/64
1	8	.878	7/8
1 1/16	8	.941	15/16
1 1/8	12	1.044	1 3/64
1 1/8	7	.986	63/64
1 3/16	7	1.048	1 3/64
1 1/4	12	1.169	1 11/64
1 1/4	7	1.111	1 7/64
1 5/16	7	1.173	1 11/64
1 3/8	12	1.294	1 19/64
1 3/8	6	1.213	1 7/32
1 1/2	12	1.419	1 27/64
1 1/2	6	1.338	1 11/32
1 5/8	5 1/2	1.448	1 29/64
1 3/4	5	1.555	1 9/16
1 7/8	5	1.680	1 11/16
2	4 1/2	1.783	1 25/32
2 1/8	4 1/2	1.909	1 29/32
2 1/4	4 1/2	2.034	2 1/32
2 3/8	4	2.131	2 1/8
2 1/2	4	2.256	2 1/4
2 5/8	4	2.381	2 3/8
2 3/4	4	2.506	2 1/2
2 7/8	3 1/2	2.597	2 19/32
3	3 1/2	2.722	2 23/32
3 1/8	3 1/2	2.847	2 27/32
3 1/4	3 1/2	2.972	2 31/32
3 3/8	3 1/4	3.075	3 1/16
3 1/2	3 1/4	3.200	3 3/16
3 5/8	3 1/4	3.325	3 5/16
3 3/4	3	3.425	3 7/16
4	3	3.675	3 11/16

11.16.0 Common Material R-Values

R-value is a unit of measure for the rate of heat flow through a given thickness material(s) by conduction. It can include a cavity that incorporates air space reflective insulation. It is measured by the temperature difference between outside surfaces required to cause one **BTU** to flow through one square hour. A **BTU,** (British Thermal Unit), is the amount of heat required to raise temperature of one pound of water 1°F.

MATERIAL	R-value	MATERIAL	R-value	MATERIAL	R-value
1" mineral wool	3.70	3½" fiberglass	13.48	3" honeycomb	2.59
1/2" gypsum	0.45	½" mineral tile	1.19	3" isocyanurate	22.5
1/2" plywood	0.02	1" isocyanurate	7.50	3" polystyrene	12.0
1/8" floor tile	0.05	1" polystyrene	4.00	3" polyurethane	17.6
1/8" hardboard	0.09	1" wood core door	1.96	8" con. block	1.11
3/16" hardboard	0.14	6" fiberglass	19.00	insulated glass	1.65
5/8" gypsum	0.56	l" polyurethane	5.88	single glass pane	0.94

11.17.0 Conversion Factors—Power, Pressure, Energy

Power

Multiply	By	To Get
Boiler hp	33.472	Btu/hr
Boiler hp	34.5	lbs H_2O evap. at 212°F
Horsepower	2.540	Btu/hr
Horsepower	550	ft-lb/sec
Horsepower	33.000	ft-lb/min
Horsepower	42.42	Btu/min
Horsepower	0.7457	Kilowatts
Kilowatts	3.415	Btu/hr
Kilowatts	56.92	Btu/min
Watts	44.26	ft-lb/min
Watts	0.7378	ft-lb/sec
Watts	0.05692	Btu/min
Tons refrig.	12.000	Btu/hr
Tons refrig.	200	Btu/min
Btu/hr	0.00002986	Boiler hp
lb H_2O evap. at 212°F	0.0290	Boiler hp
Btu/hr	0.000393	Horsepower
ft-lb/sec	0.00182	Horsepower
ft-lb/min	0.0000303	Horsepower
Btu/min	0.0236	Horsepower
Kilowatts	1.341	Horsepower
Btu/hr	0.000293	Kilowatts
Btu/min	0.01757	Kilowatts
ft-lb/min	0.02259	Watts
ft-lb/sec	1.355	Watts
Btu/min	1.757	Watts
Btu/hr	0.0000833	Tons refrig.
Btu/min	0.005	Tons refrig.

Energy

Multiply	By	To Get
Btu	778	ft-lb
Btu	0.000393	hp-hr
Btu	0.000293	kw-hr
Btu	0.0010307	(lbs H_2O evap. at 212°F
Btu	0.293	Watt-hr
ft-lb	0.3765	Watt-hr
Latent heat) of ice	143.33	Btu/lb H_2O
lb H_2O evap.) at 212°F	0.284	kw-hr
lb H_2O evap.) at 212°F	0.381	hp-hr
ft-lb	0.001287	Btu
hp-hr	2,540	Btu
kw-hr	3,415	Btu
lb H_2O evap.) at 212°F	970.4	Btu
Watt-hr	3.415	Btu
Watt-hr	2,656	ft-lb
Btu/lb H_2O	0.006977	(Latent heat of ice
kw-hr	3.52	(lb H_2O evap. at 212°F
hp-hr	2.63	(lb. H_2O evap. at 212°F

Pressure

Multiply	By	To Get
atmospheres	29.92	(in Mercury (at 62°F)
atmospheres	406.8	(in H_2O (at 62°F)
atmospheres	33.90	(ft. H_2O (at 62°F)
atmospheres	14.70	lb/in²
atmospheres	1.058	ton/ft²
in. H_2O) (at 62°F)	0.0737	(in. Mercury (at 62°F)
ft H_2O) (at 62°F)	0.881	(in. Mercury (at 62°F)
ft H_2O) (at 62°F)	0.4335	lb/in²
ft H_2O) (at 62°F)	62.37	lb/ft²
in. Mercury) (at 62°F)	70.73	lb/ft²
in. Mercury) (at 62°F)	0.4912	lb/in²
in. Mercury) (at 62°F)	0.03342	atmospheres
in. H_2O) (at 62°F)	0.002458	atmospheres
ft. H_2O) (at 62°F)	0.0295	atmospheres
lb/in²	0.0680	atmospheres
ton/ft²	0.945	atmospheres
in. Mercury) (at 62°F)	13.57	(in. H_2O (at 62°F)
in. Mercury) (at 62°F)	1.131	(ft H_2O (at 62°F)
lb/in²	2.309	(ft H_2O (at 62°F)
lb/ft²	0.01603	(ft H_2O (at 62°F)
lb/ft²	0.014138	(in. Mercury (at 62°F)
lb/in²	2.042	(in. Mercury (at 62°F)
lb/in²	0.0689	Bar
lb/in²	0.0703	kg/cm²

Velocity of Flow

Multiply	By	To Get
ft/min	0.01139	miles/hr
ft/min	0.01667	ft/sec
cu ft/min	0.1247	gal/sec
cu ft/sec	448.8	gal/min
miles/hr	88	ft/min
ft/sec	60	ft/min
gal/sec	8.02	cu ft/min
gal/min	0.002228	cu ft/sec

Heat Transmission

Multiply	By	To Get
Btu/in) /sq ft /hr/°F	0.0833	(Btu/ft /sq ft /hr/°F
Btu/ft) /sq ft /hr /°F	12	(Btu/in /sq ft /hr/ °F

Weight

Multiply	By	To Get
lb	7.000	grains
lb H_2O (60°F)	0.01602	cu ft H_2O
lb H_2O (60°F)	0.1198	gal H_2O
tons (long)	2.240	lb
tons (short)	2.000	lb
grains	0.000143	lb
cu ft H_2O	62.37	lb H_2O (60°F)
gal H_2O	8.3453	lb H_2O (60°F)
lb	0.000446	tons (long)
lb	0.000500	tons (short)

Circular Measure

Multiply	By	To Get
Degrees	0.01745	Radians
Minutes	0.00029	Radians
Diameter	3.142	Circumference
Radians	57.3	Degrees
Radians	3,438	Minutes
Circumference	0.3183	Diameter

Volume

Multiply	By	To Get
Barrels (oil)	42	gal (oil)
cu ft	1.728	cu in
cu ft	7.48	gal
cu in	0.00433	gal
gal (oil)	0.0238	barrels (oil)
cu in	0.000579	cu ft
gal	0.1337	cu ft
gal	231	cu in

Temperature

F = (°C x 1.8) + 32
C = (°F - 32) ÷ 1.8

Fractions and Decimals

Multiply	By	To Get
Sixty-fourths	0.015625	Decimal
Thirty-seconds	0.03125	Decimal
Sixteenths	0.0625	Decimal
Eighths	0.125	Decimal
Fourths	0.250	Decimal
Halves	0.500	Decimal
Decimal	64	Sixty-fourths
Decimal	32	Thirty-seconds
Decimal	16	Sixteenths
Decimal	8	Eighths
Decimal	4	Fourths
Decimal	2	Halves

Gallons shown are U.S. standard.

11.18.0 Useful Engineering Tables—Schedule 40 Pipe Dimensions, Diameters of Circles, and Drill Sizes

Schedule 40 Pipe, Standard Dimensions

Size (in)	Diameters		Nominal Thick-ness (in)	Circumference		Transverse Areas			Length of Pipe per sq ft		Length of Pipe Containing One Cubic Foot	Nominal Weight per foot		Number Threads per inch of Screw
	External (in)	Approx-imate Internal (in)		External (in)	Internal (in)	External (sq in)	Internal (sq in)	Metal (sq in)	External Surface Feet	Internal Surface Feet	Feet	Plain Ends	Threaded and Coupled	
1/4	0.540	0.364	0.088	1.696	1.114	0.229	0.104	0.125	7.073	10.493	1383.789	0.424	0.425	18
1/4	0.675	0.493	0.091	2.121	1.549	0.358	0.191	0.167	5.658	7.747	754.360	0.567	0.568	18
1/2	0.640	0.622	0.109	2.639	1.954	0.554	0.304	0.250	4.547	6.141	473.906	0.850	0.852	14
3/4	1.050	0.824	0.113	3.299	2.589	0.866	0.533	0.333	3.637	4.635	270.034	1.130	1.134	14
1	1.315	1.049	0.133	4.131	3.296	1.358	0.864	0.494	2.904	3.641	166.618	1.678	1.684	11 1/2
1 1/4	1.660	1.380	0.140	5.215	4.335	2.164	1.495	0.669	2.301	2.767	96.275	2.272	2.281	11 1/2
1 1/2	1.900	1.610	0.145	5.969	5.058	2.835	2.036	0.799	2.010	2.372	70.733	2.717	2.731	11 1/2
2	2.375	2.067	0.154	7.461	6.494	4.430	3.355	1.075	1.608	1.847	42.913	3.652	3.678	11 1/2
2 1/2	2.675	2.469	0.203	9.032	7.757	6.492	4.788	1.704	1.328	1.547	30.077	5.793	5.819	8
3	3.500	3.068	0.216	10.996	9.638	9.621	7.393	2.228	1.091	1.245	19.479	7.575	7.616	8
3 1/2	4.000	3.548	0.226	12.566	11.146	12.566	9.886	2.680	0.954	1.076	14.565	9.109	9.202	8
4	4.500	4.026	0.237	14.137	12.648	15.904	12.730	3.174	0.848	0.948	11.312	10.790	10.899	8
5	5.563	5.047	0.258	17.477	15.856	24.306	20.006	4.300	0.686	0.756	7.198	14.617	14.810	8
6	6.625	6.065	0.280	20.813	19.054	34.472	28.891	5.581	0.576	0.629	4.984	18.974	19.185	8
8	8.625	7.981	0.322	27.096	25.073	58.426	50.027	8.399	0.442	0.478	2.878	28.554	28.809	8
10	10.750	10.020	0.365	33.772	31.479	90.763	78.855	11.908	0.355	0.381	1.826	40.483	41.132	8
12	12.750	11.938	0.406	40.055	37.699	127.640	111.900	15.740	0.299	0.318	1.288	53.600	—	—
14	14.000	13.125	0.437	43.982	41.217	153.940	135.300	18.640	0.272	0.280	1.069	63.000	—	—
16	16.000	15.000	0.500	50.265	47.123	201.050	176.700	24.350	0.238	0.254	0.817	78.000	—	—
18	18.000	16.874	0.563	56.548	52.998	254.850	224.000	30.850	0.212	0.226	0.643	105.000	—	—
20	20.000	18.814	0.593	62.831	59.093	314.150	278.000	36.150	0.191	0.203	0.519	123.000	—	—
24	24.000	22.626	0.687	75.398	71.063	452.400	402.100	50.300	0.159	0.169	0.358	171.000	—	—

Equivalent Length of Pipe to be Added for Fittings—Schedule 40 Pipe

Pipe Size (in)	Length in Feet to be Added Run				
	Standard Elbow	Side Outlet Tee	Gate Valve*	Globe Valve*	Angle Valve*
1/2	1.3	3	0.3	14	7
3/4	1.8	4	0.4	18	10
1	2.2	5	0.5	23	12
1 1/4	3.0	6	0.6	29	15
1 1/2	3.5	7	0.8	34	16
2	4.3	8	1.0	46	22
2 1/2	5.0	11	1.1	54	27
3	6.5	13	1.4	66	34
3 1/2	8.0	15	1.6	80	40
4	9.0	18	1.9	92	45
5	11.0	22	2.2	112	56
6	13.0	27	2.8	136	67
8	17.0	35	3.7	180	92
10	21.0	45	4.6	230	112
12	27.0	53	5.5	270	132

*Valve in full open position

Thermal Expansion of Pipe

*From Piping Handbook, by Walker and Crocker, by special permission.

This table gives the expansion from −20°F to temperature in question. To obtain the amount of expansion between any two temperatures take the difference between the figures in the table for those temperatures. For example, if cast iron pipe is installed at a temperature of 80°F and is operated at 240°F, the expansion would be 1.780 − 0.649 = 1.131 in.

Temp (°F)	Elongation in Inches per 100 Ft from −20°F Up			
	Cast Iron Pipe	Steel Pipe	Wrought Iron Iron Pipe	Copper Pipe
−20	0.000	0.000	0.000	0.000
0	0.127	0.145	0.152	0.204
20	0.255	0.293	0.306	0.442
40	0.390	0.430	0.465	0.655
60	0.518	0.593	0.620	0.888
80	0.649	0.725	0.780	1.100
100	0.787	0.898	0.939	1.338
120	0.926	1.055	1.110	1.570
140	1.051	1.209	1.265	1.794
160	1.200	1.368	1.427	2.008
180	1.345	1.526	1.597	2.255
200	1.495	1.691	1.778	2.500
240	1.780	2.020	2.110	2.960
280	2.085	2.350	2.465	3.422
320	2.395	2.690	2.800	3.900
360	2.700	3.029	3.175	4.380
400	3.008	3.375	3.521	4.870
500	3.847	4.296	4.477	6.110
600	4.725	5.247	5.455	7.388

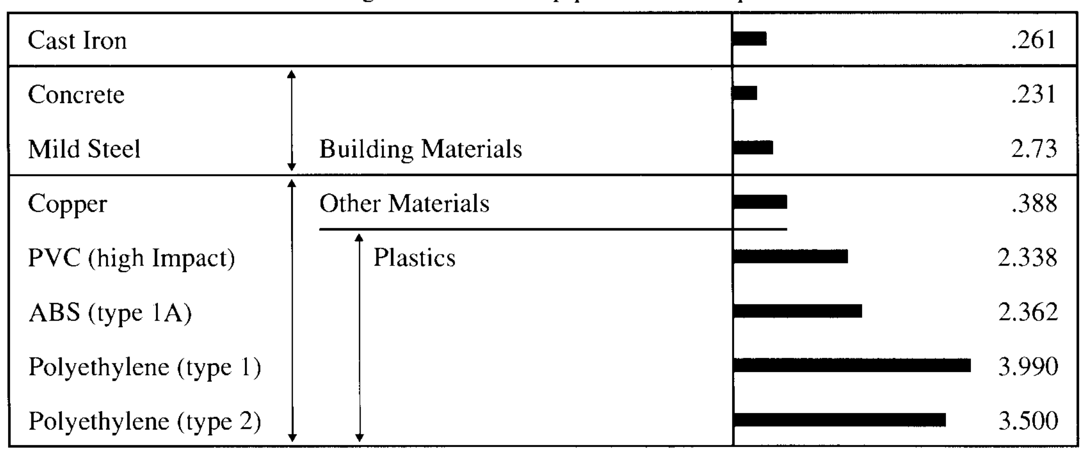
Diameters and Areas of Circles and Drill Sizes

Drill Size	Dia.	Area	Drill Size	Dia.	Area	Drill Size	Dia.	Area	Drill Size	Dia.	Area
3/64	.0469	.00173	27	.1440	.01629	C	.2420	.04600	27/64	.4219	.13920
55	.0520	.00212	26	.1470	.01697	D	.2460	.04753	7/16	.4375	.15033
54	.0550	.00238	25	.1495	.01705	1/4	.2500	.04909	29/64	.4531	.16117
53	.0595	.00278	24	.1520	.01815	E	.2500	.04909	15/32	.4688	.17257
1/16	.0625	.00307	23	.1540	.01863	F	.2570	.05187	31/64	.4844	.18398
52	.0635	.00317	5/32	.1562	.01917	G	.2610	.05350	1/2	.500	.19635
51	.0670	.00353	22	.1570	.01936	17/64	.2656	.05515	33/64	.5156	.20831
50	.0700	.00385	21	.1590	.01986	H	.2660	.05557	17/32	.5313	.22166
49	.0730	.00419	20	.1610	.02036	I	.2720	.05811	9/16	.5625	.24850
48	.0760	.00454	19	.1660	.02164	J	.2770	.06026	19/32	.5937	.27688
5/64	.0781	.00479	18	.1695	.02256	K	.2810	.06202	5/8	.6250	.30680
47	.0785	.00484	11/64	.1719	.02320	9/32	.2812	.06213	21/32	.6562	.33824
46	.0810	.00515	17	.1730	.02351	L	.2900	.06605	11/16	.6875	.37122
45	.0820	.00528	16	.1770	.02461	M	.2950	.06835	23/32	.7187	.40574
44	.0860	.00581	15	.1800	.02545	19/64	.2969	.06881	3/4	.7500	.44179
43	.0890	.00622	14	.1820	.02602	N	.3020	.07163	25/32	.7812	.47937
42	.0935	.00687	13	.1850	.02688	5/16	.3125	.07670	13/16	.8125	.51849
3/32	.0938	.00690	3/16	.1875	.02761	O	.3160	.07843	27/32	.8437	.55914
41	.0960	.00724	12	.1890	.02806	P	.3230	.08194	7/8	.8750	.60132
40	.0980	.00754	11	.1910	.02865	21/64	.3281	.08449	29/32	.9062	.64504
39	.0995	.00778	10	.1935	.02941	Q	.3320	.08657	15/16	.9375	.69029
38	.1015	.00809	9	.1960	.03017	R	.3390	.09026	31/32	.9687	.73708
37	.1040	.00850	8	.1990	.03110	11/32	.3438	.09281	1	1.0000	.78540
36	.1065	.00891	7	.2010	.03173	S	.3480	.09511	1-1/16	1.0625	.88664
7/64	.1094	.00940	13/64	.2031	.03241	T	.3580	.10066	1-1/8	1.1250	.99402
35	.1100	.00950	6	.2040	.03268	23/64	.3594	.10122	1-3/16	1.1875	1.1075
34	.1110	.00968	5	.2055	.03317	U	.3680	.10636	1-1/4	1.2500	1.2272
33	.1130	.01003	4	.2090	.03431	3/8	.3750	.11045	1-5/16	1.3125	1.3530
32	.1160	.01039	3	.2130	.03563	V	.3770	.11163	1-3/8	1.3750	1.4859
31	.1200	.01131	7/32	.2188	.03758	W	.3860	.11702	1-7/16	1.4375	1.6230
1/8	.1250	.01227	2	.2210	.03836	25/64	.3906	.11946	1-1/2	1.5000	1.7671
30	.1285	.01242	1	.2280	.04083	X	.3970	.12379	1-5/8	1.6250	2.0739
29	.1360	.01453	A	.2340	.04301	Y	.4040	.12819	1-3/4	1.7500	2.4053
28	.1405	.01550	15/64	.2344	.04314	13/32	.4062	.12962	1-7/8	1.8750	2.7612
9/64	.1406	.01553	B	.2380	.0449	Z	.4130	.13396	2	2.0000	3.1416

11.19.0 Thermal Expansion of Various Materials

Material	Inches per inch 10^{-6} X per °F	Inches per 100′ of pipe per 100°F.	Ratio-assuming cast iron equals 1.00
Cast iron	6.2	0.745	1.00
Concrete	5.5	0.66	.89
Steel (mild)	6.5	0.780	1.05
Steel (stainless)	7.8	0.940	1.26
Copper	9.2	1.11	1.49
PVC (high impact)	55.6	6.68	8.95
ABS (type 1A)	56.2	6.75	9.05
Polyethylene (type 1)	94.5	11.4	15.30
Polyethylene (type 2)	83.3	10.0	13.40

Here is the *actual* increase in length for 50 feet of pipe and 70° temperature rise.



11.20.0 Metric Conversion of ASTM Diameter and Wall Thickness Designations and Metric Conversion Scales (Temperature and Measurements)

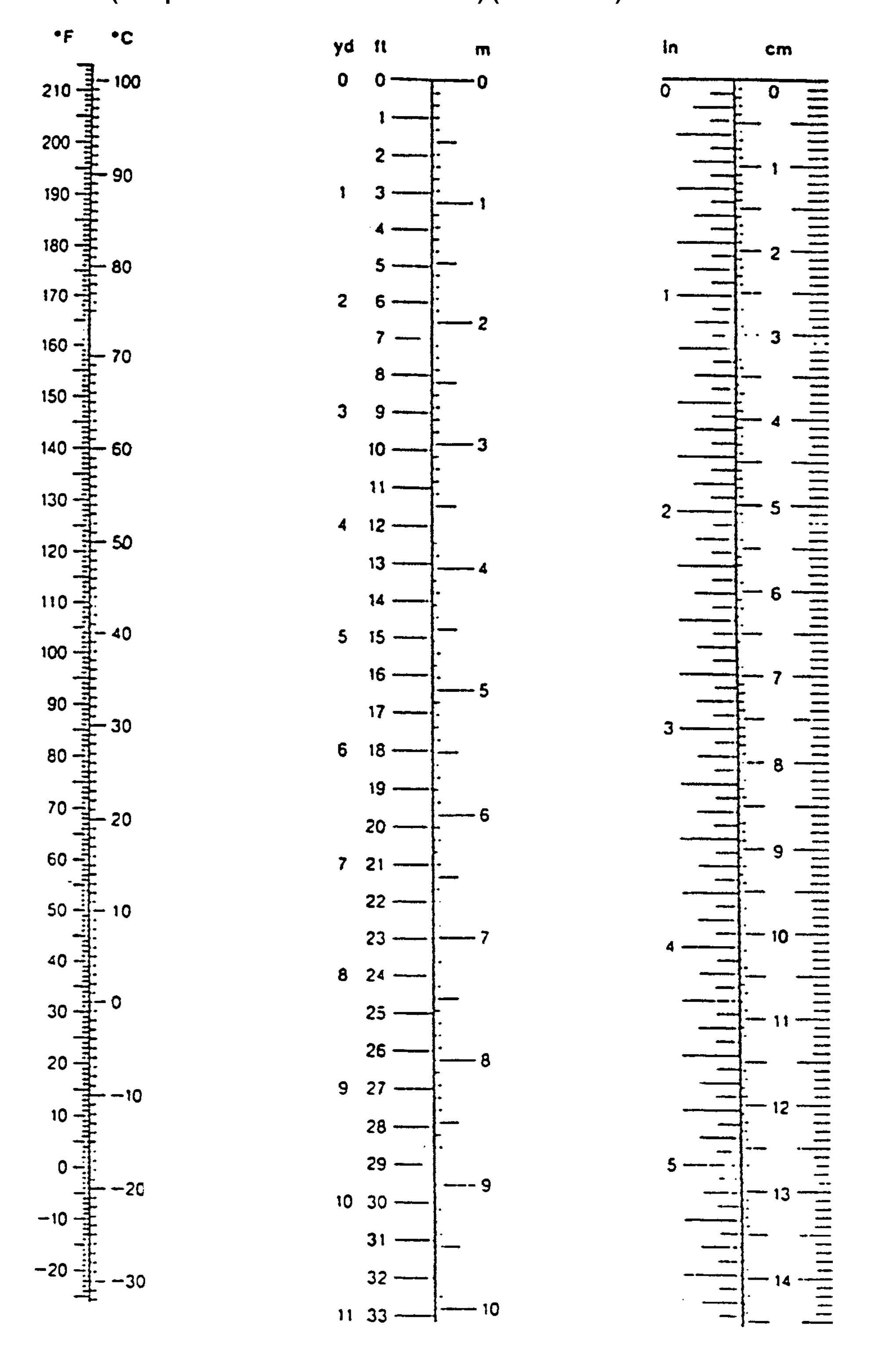
Metric conversion of ASTM diameter designations

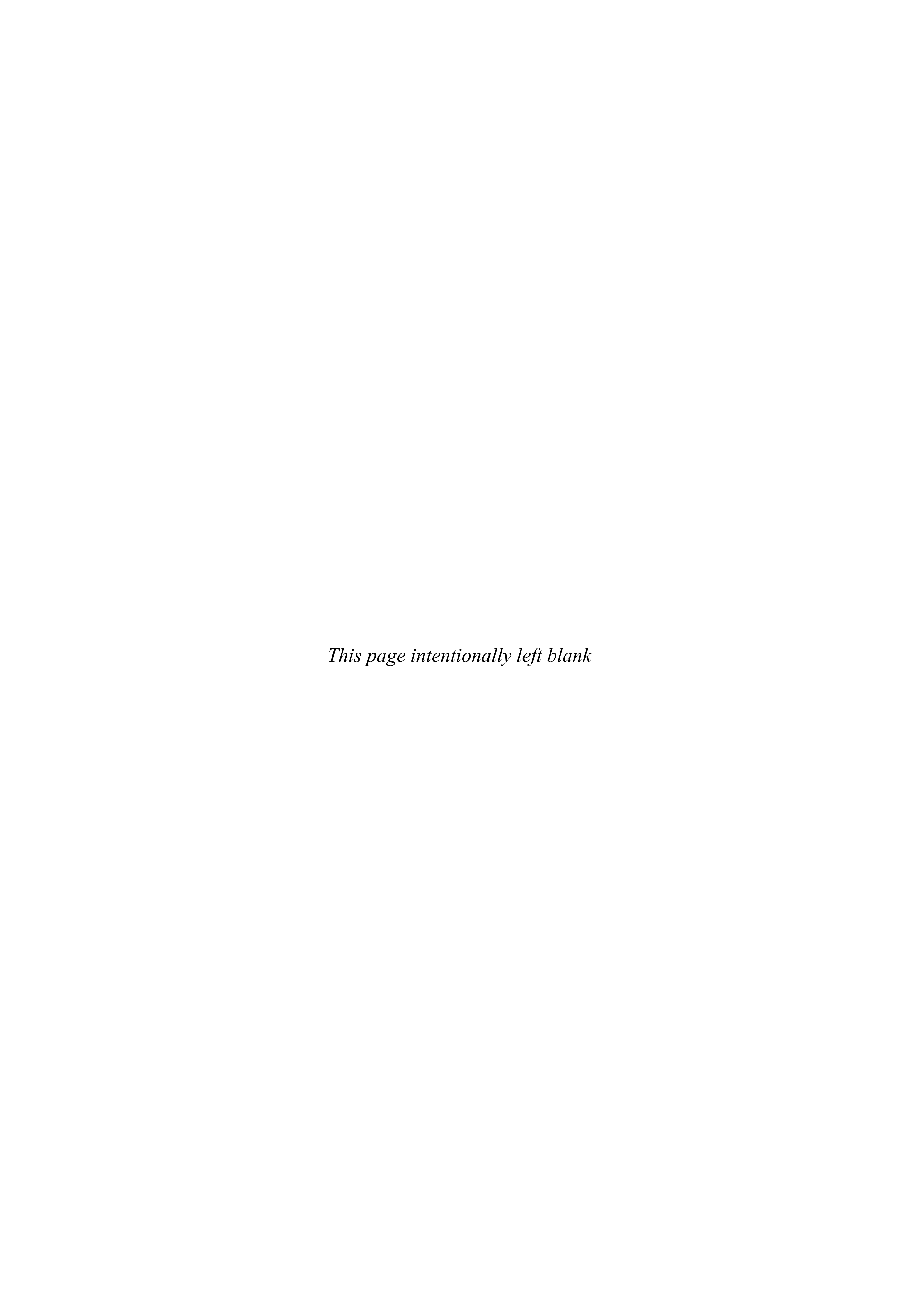
in	mm	in	mm	in	mm	in	mm
6	150	30	750	57	1425	96	2400
8	200	33	825	60	1500	102	2550
10	250	36	900	63	1575	108	2700
12	300	39	975	66	1650	114	2850
15	375	42	1050	69	1725	120	3000
18	450	45	1125	72	1800	132	3300
21	525	48	1200	78	1950	144	3600
24	600	51	1275	84	2100	156	3900
27	675	54	1350	90	2250	168	4200

Metric conversion of ASTM wall thickness designations

in	mm	in	mm	in	mm	in	mm
1	25	3-1/8	79	5	125	8	200
1-1/2	38	3-1/4	82	5-1/4	131	8-1/2	213
2	50	3-1/2	88	5-1/2	138	9	225
2-1/4	56	3-3/4	94	5-3/4	144	9-1/2	238
2-3/8	59	3-7/8	98	6	150	10	250
2-1/2	63	4	100	6-1/4	156	10-1/2	263
2-5/8	66	4-1/8	103	6-1/2	163	11	275
2-3/4	69	4-1/4	106	6-3/4	169	11-1/2	288
2-7/8	72	4-1/2	113	7	175	12	300
3	75	4-3/4	119	7-1/2	188	12-1/2	313

11.20.0 Metric Conversion of ASTM Diameter and Wall Thickness Designations and Metric Conversion Scales (Temperature and Measurements) (*Continued*)





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